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An optimum mixture of virgin rice straw pulp and recycled old newsprint (ONP) pulp and their antimicrobial activity

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ABSTRACT

Recycled fibres are important sources for paperboard industry. There are various approaches to enhance the strength of recycled fibres. These approaches include mechanical treatment, chemical addition, and physical fractionation as well as blending with virgin fibres. In this study, two types of deinked old newsprint (ONP) pulp were subjected to blending with virgin fibres of rice straw. The ONP pulp was blended with rice straw pulp at 4 intervals ranging from 0 to 100% addition. It was observed that blending ONP with rice straw pulp had enhanced the strength of the virgin fibre and vise versa. The modification of rice straw fibres was visually evaluated by scanning electron microscopy (SEM). It was observed that the addition of the flexible ONP pulp type2 seemed to fill up the voids in the paper sheet and created more bonding with rice straw fibres. Shrimps exoskeletons poweder, borax and cactus peel extract were added to paper board made from 50% rice straw+50% ONP type2 pulp at percent of 2% based on oven dry weight pulp. The antimicrobial activity of each of these three additives was studied.

KEYWORDS

Blended pulp;
Rice straw;
Antimicrobial activity.

INTRODUCTION

Pulp blending is a common practice in papermaking to achieve desired properties of end products[1]. showed that the mixing of hardwood chemical pulp with chemical mechanical pulp improved bulk and light scattering properties and also improved interfiber bonding strength as compared to chemical pulp alone. The addition of abaca pulp to softwood pulp increased tear strength, fracture toughness, and folding endurance for the isotropic sheets, but the tensile strength slightly decreased[2]. Banana stem can be blended along with agro residues raw materials prior to pulping up to a level of 5-20 % to improve physical strength properties without any noticeable difference in pulping and bleaching process[3]. Rice straw is one of the most important raw materials in the future for pulp and paper industry. The major problems in rice straw pulping are silica, which inhibits the recovery of black liquor in alkali pulping processes, and the high amount of fines, which cause drainage problem. Much efforts have been made to solve these problems[5]. Unfortunately, no attempt reached to commercialization. The strength properties of straw pulp are relatively poor compared to wood pulp and therefore, application to produce brown grades such as sack Kraft, bag Kraft and liner board is generally avoided. However, straw pulp as a semi-chemical pulp is extensively used to produce corrugating medium, often mixed with OCC (old corrugated container) fiber. Straw pulp component could be as high as 70 to 80% blended with 30 to 20% of OCC fiber[6]. Relatively coarse mechanical pulps, with only 10–15% incorporation of bleached chemical pulp to provide sufficient strength are used in the preparation of textured hanging stock (wallpapers). Newsprint, which is used for newspapers, inexpensive magazines, paperback books, and other low-cost publishing requirements, employs a blend of 15–35% chemical pulp stocks into the mechanical pulp, to obtain an economically thin sheet of sufficient strength to avoid breakage in modern high-speed printing presses. Also about 10% or so of mechanical pulps, particularly of stone ground wood types, may be blended into the pulps that are used for some fine papers to improve the smoothness and opacity[7]. Fibre from recycled paper is an important raw material source that offers several economic advantages to paper manufacturing. Conventionally, hydrogen peroxide is used as a lignin retaining bleaching agent of high yield mechanical and chemi - mechanical pulp. Hydrogen peroxide is commonly used to improve the brightness of wastepaper furnishes[8]. Paper and paperboard are the most widely used materials in food and drink packaging[9,10]. Improving the functionality of paper by imparting it with antimicrobial agents and ethylene scavengers can help in reducing the use of chemical additives directly on food[11]. Modern consumer opinion suggests a desire for high quality food that is more natural, minimally processed and preservative free, while remaining safe and with an extended shelf life[12]. This has driven food industry and food research towards the search for natural antimicrobial compounds such as native food preservative ingredients, herbal extractions, or antimicrobial agents derived from animals. The use of shrimps exoskeletons to produce antimicrobial activities by chitin against marine and estuarine pathogens has recently received considerable attention as a new source of novel antimicrobial substances[13]. Borax is widely used in industry, but it is forbidden as a food additive by various countries due to its high toxicity[14]. Potassium tetraborate and borax ($Na_2B_4O_7$) were evaluated for their *in vitro* activity against *Fusarium sulphureum* and for their curative and preventive efficacy against postharvest dry rot infections on potato tubers[15]. The antimicrobial activity, minimum inhibitory concentration (MIC) and minimum sterilization concentration of the extracts from cactus were studied[16]. The results showed that the wild cactus extracts (odh) had a strong inhibitory activity against Escherichia coli and Bacillus subtilis, but the activity of edible cactus (Opuntia Miloa Alta) extracts was weak. The MIC for two kinds of microorganisms are listed as follows: Escherichia coli w (odh) = 2.5%, Bacillus subtilis w (odh) = 5%; and the minimum sterilization quality fractions are: Escherichia coli w (odh) = 5%, Bacillus subtilis w (odh) = 10%. By orthogonal experiments, the best conditions for extraction are volume fraction of alcohol φ (C_2H_5OH) = 85% and pH = 4.5.

EXPERIMENTAL PART

Materials

Rice straw pulp was prepared by cooking rice straw using 5% sodium hydroxide at 80^0C in atmospheric pressure and deinked old newspaper pulp (ONP). NaOH was purchased from EL NASR PHAMEUCITICAL chemical CO., commercial pure hydrogen peroxide 50% conc. was supplied by FMC Co., Spain, $MgSO_4 \cdot 7H_2O$ was obtained from Mallinckrodt Co., Germany. Borax, Shrimps exoskeletons powder and cactus mucilage extract were used as antimicrobial additives.

Preparation of newspaper pulp

Type1: 100 O.d g newspaper were cut into pieces and immersed in hot water containing 3 wt% NaOH at liquor ratio 1:5 for 2 hours at 50^0C. After the required time, pulp was mechanically stirred and washed by water till neutrality and finally air dried.

Type2: 100 O.d g newspaper were cut into pieces, immersed in 600 ml water and mechanically stirred. The pulp slurry was put in a sealed plastic bag submerged in a water bath set at 70 °C. Commercial pure hydrogen peroxide 50% conc. was used in a percent of 5%. KOH and magnesium sulphate were added at 3% and 0.3% respectively based on O.d newspaper. After 2 hours, the bleached pulp was then thoroughly washed with water to stop the bleaching reaction and to prevent the yellowing effect of the residual alkali till neutrality followed by aceton and finally air dried. The pulp yield after repulping was 89% due to the loss of soluble fines, filler, alkali soluble paper components and contaminants during repulping and dewatering.

Hand made paper sheets tests

Carton sheets of basis weight 120 g/m^2 were made from pulp slurry according to Tappi-Standard Method using the sheet former of AB Lorentzen (Stockholm, Sweden).

Pulp slurry contains rice straw pulp, newspaper pulp type1 and newspaper pulp type2 in the following percentages:

100% rice straw pulp (S1)

33.3% rice straw pulp + 66.6% newspaper pulp type1 (S2)

50% rice straw pulp + 50% newspaper pulp type1 (S3)

100% newspaper pulp type1 (S4)

50% rice straw pulp + 50% newspaper pulp type2 (S5)

33.3% rice straw pulp + 66.6% newspaper pulp type2 (S6)

100% newspaper pulp type2 (S7)

The slurries were well stirred to ensure a uniform distribution of the fibres of the two mixed pulps. The sheets were then placed for conditioning at 65% relative humidity, and temperature ranging from 18 to 20 æ%C. The sheets were tested for tensile strength according to German Standard method by means of a Karl Frank 468 tester (Weinheim–Berkenau) and burst strength according to TAPPI Standard test method 403.A.Mullen (Perkins, Chicopee, MA, USA) was used. Stiffness was determined using TABER tester model 150B. Also, scanning electron micrographs (SEM) were taken using FEI INSPECTS Company, Philips, Holland.

Antimicrobial activity

Hand-made paper sheets made from 50% rice straw pulp and 50% ONP type2 were considered to study the antimicrobial activity of three additives namely, Shrimps exoskeletons powder, borax and cactus peel extract. Each additive was added to the pulp mixture and stirred before paper making by 24 hours at 2% based on oven dry weight pulp. Paper board samples containing these additives were given numbers 7, 8, and 9 respectively.

The ability to inhibit the growth of Gram-positive and Gram-negative bacteria, yeasts and filamentous fungi was observed using an overlay method[17].

Antimicrobial assay

Strains used

The common pathogenic and food spoilage microorganisms were selected for their relevance in bakery products and other food: the gram-positive bacteria; *Bacillus cereus* and the gram negative bacteria; *Escherichia coli*, yeasts *such as Candida albicans* and fungi *(Asperagillus niger).*

Media used

The bacteria were slanted on nutrient agar (Merck, Darmstadt, Germany), yeast was slanted and mentioned on Sabaroud's agar medium (Lab M., Bury, Lancashire, UK) and fungi were slanted and mentioned on the potato Dextrose Agar medium (Lab M Limited, Bury, Lancashire, UK). Mueller-Hinton agar (Lab M., Bury, Lancashire, UK) following the manufacturer's instructions was used for the assay.

Bioassay

The antibacterial screening was essentially by the disk diffusion agar method described by[18]. The organisms will be streaked in radial patterns on the agar plates. Plates will be incubated under aerobic conditions at 37°C and 28 °C for 24 h and 48 h for bacteria and fungi respectively. In order to obtain comparable results, all the prepared solutions were treated under the same conditions in the same incubated plates. All tests were performed for three replicates. Plates were examined for evidence of antimicrobial activities, represented by a zone of inhibition of microorganism's growth around the paper disk and diameters of clear zones were expressed in millimeters (mm). www.eucast.org, www.jac.oupjournals.org/content/vol48/suppl_1/2001

RESULTS AND DISCUSSION

Unblended paperboard properties

The properties of the paperboard made from rice straw soda pulp or recycled ONP are shown in *TABLE 1, Figure 1 and Figure 2.* Compared to rice straw pulp, fibres of recycled pulp are more easily compressed into the voids of the sheet, indicating flexibility; however rice straw fibres are stiffer and not so easily compressible. This may be attributed to the high silica content in the pulp. Pulping condition did not reduce silica content more than 14.4%. Recycled ONP type1 and type2 had tensile strengths higher than rice straw pulp because ONP originally contains chemical pulp. In the deinking step, the lignin and various extractives – the coloured substances - were dissolved or modified, leaving behind only the white cellulose[20]. Also, TABLE 1 indicates that burst strength of rice straw pulp 0.5880 Kg/cm^2 is lower than that of ONP deinked by hydrogen peroxide 1.1505 Kg/cm^2.

TABLE 1 : Properties of paperboard from blended rice straw pulp and recycled old newsprint pulp

Rice straw%	Recycled ONP% type1	Recycled ONP% type2	Stiffness,Kg.cm	Burst Kg/cm^2
100	0	0	25	0.5880
33.3	66.6	-----	25	0.562
50	50	-----	20	0.5369
0	100	----	20	0.6112
50	-----	50	20	0.9715
33.3	----	66.6	25	1.124
0	-----	100	20	1.1505

Blended paperboard properties

The properties of the paperboard made from mixtures of the rice straw soda- pulp and recycled ONP are shown in TABLE 1. The paperboard properties were greatly affected by the rice straw pulp incorporated, with the changes dependent on the particular property, percentage of blending and the type of recycled paper used[21]. By blending both pulps, a significant improvement in all properties was obtained. Tensile strength was increased by increasing the amount of rice straw pulp in the blend from 33.3% to 50% as shown in Figure2. This is due to flexibility of ONP pulp and inter–fiber bonding and the presence of short fragments in the straw pulp producing a highly bonded structure. Thus, virgin nature of rice straw pulp improved the structural and mechanical properties of the blend. Among these blends, 50/50 ONP type2 had the best tensile strength more than other blends. 33.3% rice straw pulp + 66.6 ONP type2 blend sample had better burst strength and stiffness than 50/50 ONP type1 and 50/50 ONP type2. Stiffness and strength are two basic paperboard properties which have a major influence on the mechanical paperboard performance of paperboard. They have a crucial effect on the board's protective properties and also influence carton shape and appearance. The laws of nature make it impossible to maximize strength and stiffness simultaneously. Every application is a compromise to find the best balance. The physical properties of paperboard are largely determined by the types and amounts of fibres used. The

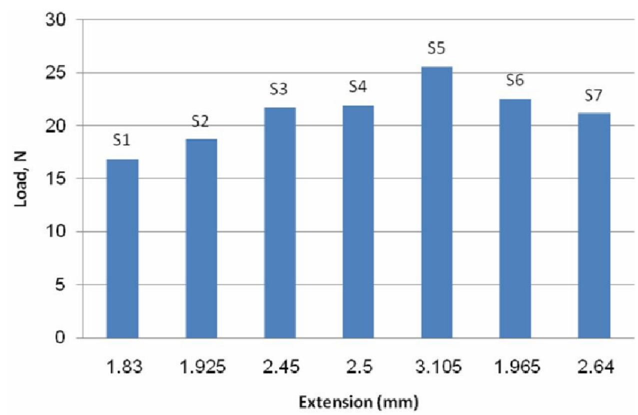

Figure 1 : Load-extension curves for rice straw pulp blended with ONP

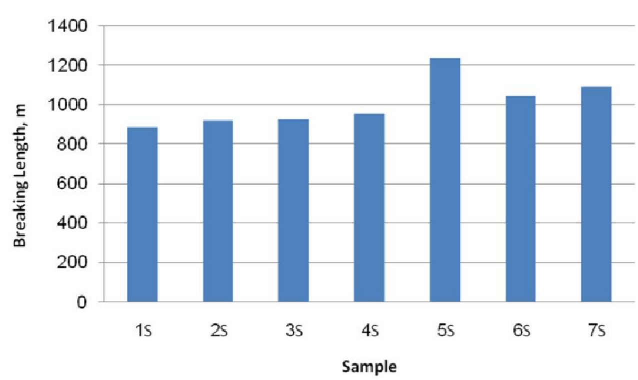

Figure 2 : The influence of blending rice straw pulp with ONP on breaking length

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two main types of fibres used for paperboard are mechanically or chemically processed. Due to the very different treatment of wood in the mechanical and chemical processes, the resulting properties of the two types of fibre differ considerably. When a paper product is recycled, the repulped fibres still ultimately originate from the same two sources, i.e. mechanical and chemical fibres. During recycling, the fibres become contaminated and worn (lose strength). Therefore primary fibres are always needed to maintain the quality of recycled products. In other words, the strength of recycled ONP was greatly restored when beaten virgin rice straw fibres were used. Beating has created internal and external fibrillation of the fibres. This in turn had created more bonded areas in the blended handsheets. It is also observed that the weak rice straw pulp was modified by blending with recycled ONP.

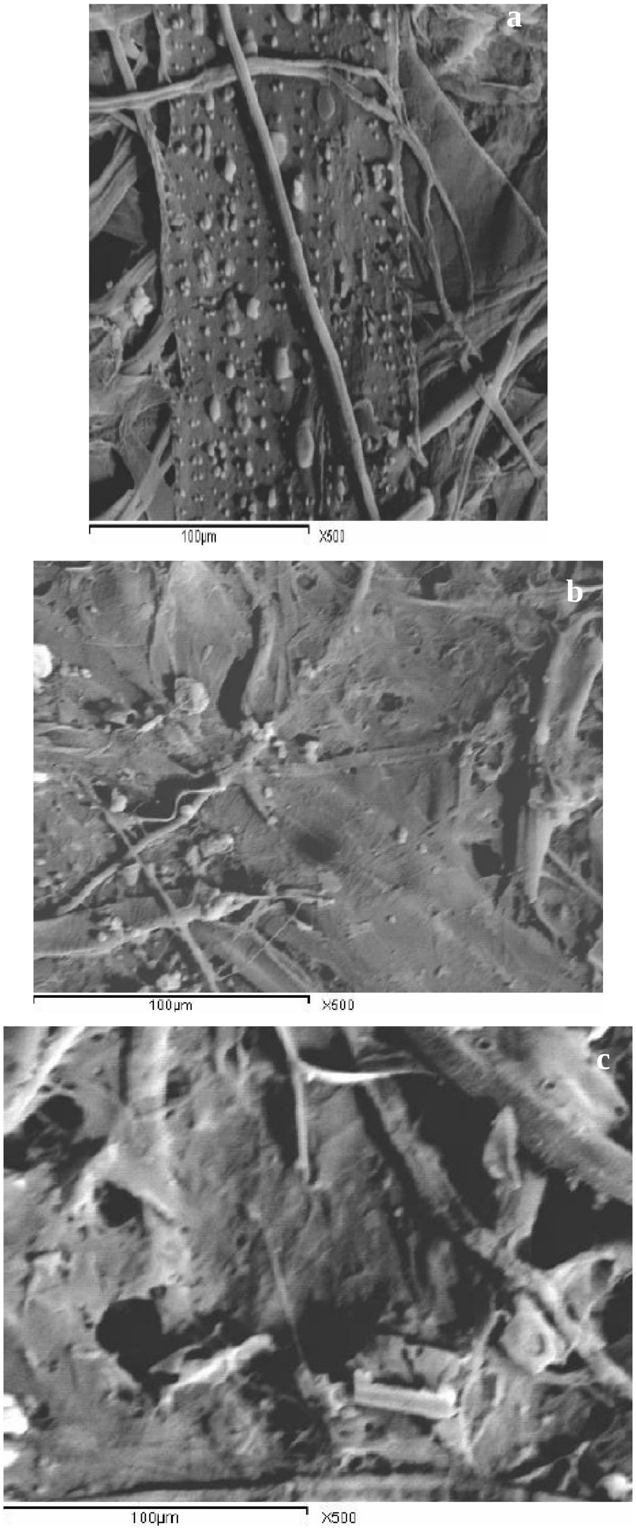

Figure 3 : Scanning electron micrographs of the surface of hand sheets of 50% rice straw pulp + 50% ONP type1 (a), 50% rice straw pulp + 50% ONP pulp type2 (b) and ONP type2 (c)

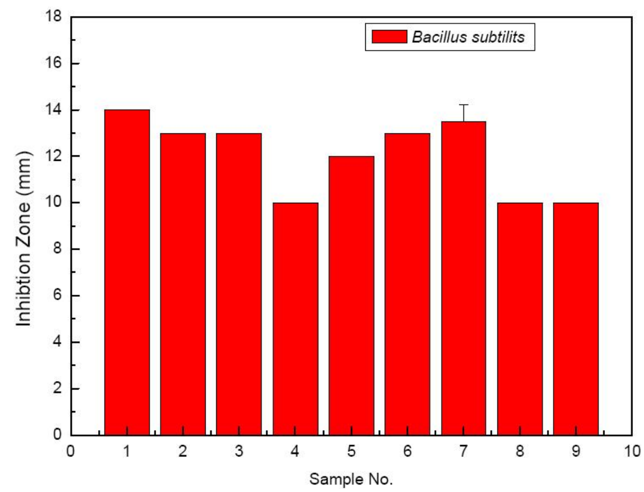

Figure 4 : The antimicrobial activity of the paperboard made from rice straw pulp and /ONP pulp blend against *Bacillus subtitles*

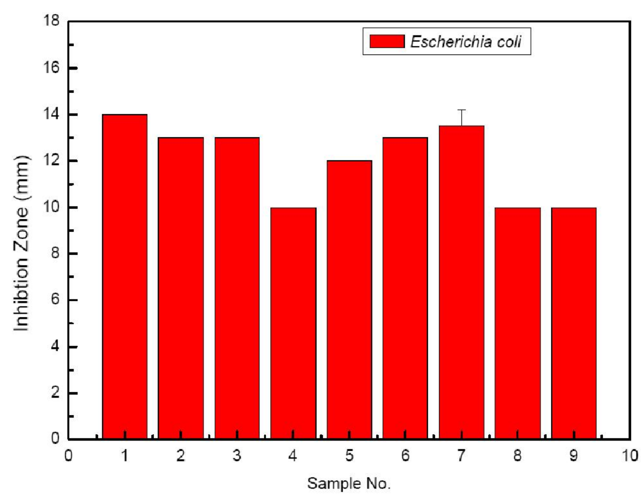

Figure 5 : The antimicrobial activity of the paperboard made from rice straw pulp and /ONP pulp blend against *Escherichia coli*

Scanning electron microscopy

The modification of rice straw fibres was visually evaluated by scanning electron microscopy (SEM).It was observed that the addition of the flexible ONP pulp type2 seemed to fill up the voids in the sheet and created more bonding with rice straw fibres (Figure 3b).

Figure 3a depicts the surface structure of 50% rice straw pulp + 50% ONP type1, Figure 3b illustrates the addition of 50% rice straw pulp to 50% ONP pulp type2, while Figure 3c shows the ONP type2 fibres which contain more voids.

Antimicrobial activity of blended paperboard

Bacillus subtitles

The results in Figure 1 showed that: the samples no. 1,2,3,6 and 7 showed a strong inhibitory effect, while a moderate inhibitory effect was observed using sample no. 5. On the other hand, a weak inhibitory effect was noticed from samples no.4, 6 and 9.

Escherichia coli

The results in Figure 4 showed that most of the samples had a weak inhibitory effect, except samples no. 1 and 2 that showed a strong inhibitory effect, while *a* moderate inhibitory effect was observed from the samples no. 8 and 9.

Candida albicans

The results illustrated *in* Figure 4 indicated that a strong inhibitory effect was determined from samples no.1,2,3,4 and 9. Furthermore, samples no. 5 and 6 showed a moderate effect, and a weak inhibitory effect was observed from samples no. 7 and 8.

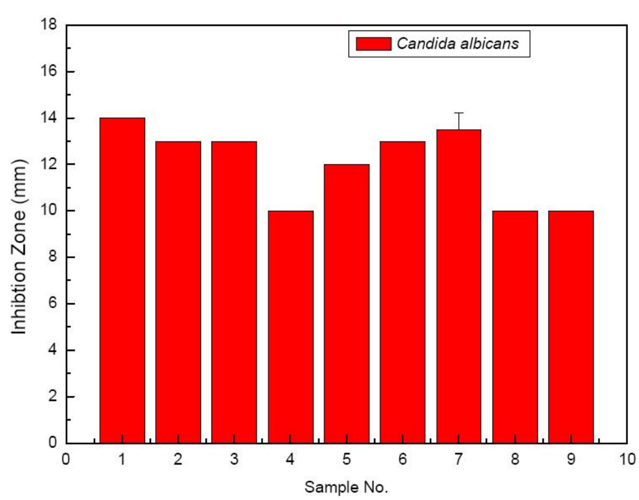

Figure 6 : The antimicrobial activity of the paperboard made from rice straw pulp and /ONP pulp blend against *Candida albicans*

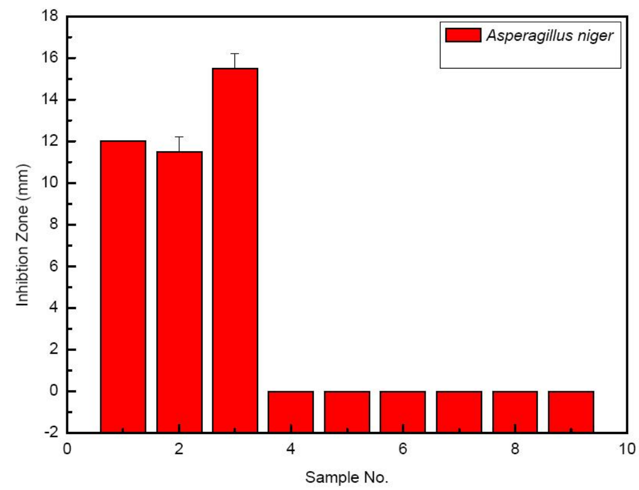

Figure 7 : The antimicrobial activity of the paperboard made from rice straw pulp and /ONP pulp blend against *Asperagillus niger*.

Asperagillus niger

The results in Figure 5 showed that most of the samples had not any inhibitory effect with the exception of sample no. 3 which had a strong effect and sample no. 1 which had a moderate effect.

CONCLUSION

ONP was repulped by two methods using sodium hydroxide and commercial hydrogen peroxide and blended with rice straw pulp. Recycled ONP type1 and type2 had tensile strengths higher than rice straw pulp because ONP originally contain chemical pulp. The paperboard properties made from the two blended pulps were greatly affected by the rice straw pulp incorporated, with the changes dependent on the particular property, percentage of blending and the type of recycled paper used. Tensile strength was increased by increasing the amount of rice straw pulp in the blend from 33.3% to 50%. Thus, virgin nature of rice straw pulp improved the structural and mechanical properties of the blend. Among these blends, 50/50 ONP type2 had the best tensile strength more than other blends. Shrimps exoskeletons powder, borax and cactus peel extract were added to paper board made from 50% rice straw pulp + 50% ONP type2 by 2% based on oven dry weight pulp as antimicrobial. Samples 1 to 3 have a moderate antibacterial activity on most of the pathogenic microorganisms used such as *Bacillus subtitles, Escherichia coli, Candida albicans* and *Asperagillus niger*, except sample no. 3 which has a strong inhibition activity on *Asperagillus niger*

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