International Journal of Technology (2015) 1: 63-72
ISSN 2086-9614 © IJTech 2015

AN OPTIMUM MIXTURE OF VIRGIN RICE STRAW PULP AND RECYCLED OLD NEWSPRINT PULP AND THEIR ANTIMICROBIAL ACTIVITY

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(Received: April 2014 / Revised: November 2014 / Accepted: December 2014)

ABSTRACT

Recycled fibers are an important materials source for the paperboard industry. There are various approaches to enhance the strength of recycled fibers. These approaches include mechanical treatment, chemical addition, and physical fractionation as well as blending with virgin fibers. In this study, according to the method of deinking two types of deinked old newsprint, namely Type 1 and Type 2 Old Newspaper Pulp (ONP), were subjected to blending with virgin fibers of rice straw soda pulp to make handmade paperboard sheets of 120 g/m^2 basis weight. The ONP pulp was blended with rice straw pulp at 4 intervals ranging from 0 to 100%. It was observed that blending ONP with rice straw pulp enhanced the strength of the virgin fiber. The improvement of rice straw pulp was visually evaluated by Scanning Electron Microscopy (SEM) of handmade paperboard sheets. It was observed that the addition of the flexible ONP Type 2 to rice straw pulp seemed to fill up the voids in the paper sheet and created more bonding with rice straw fibers. Shrimp exoskeleton powder, borax and cactus peel extract were added to blended pulp made from 50% rice straw + 50% ONP Type 2 pulp at percent of 2%, based on oven dry pulp weight. The antimicrobial activity of each of these three additives was studied. The results showed that most of samples have a moderate antimicrobial activity against most of the pathogenic microorganisms used such as *Bacillus subtilis*, *Escherichia coli*, *Candida albicans* and *Asperagillus niger*.

Keywords: Antimicrobial activity; Blended pulp; Mechanical; Paperboard; Rice straw

1. INTRODUCTION

Pulp blending is a common practice in papermaking to achieve the desired properties for the end products. Xu and Zhou, (2007) 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. Banana stems can be blended along with agro-residues as raw materials prior to pulping up to a level of 5–20% to improve the physical strength properties without any noticeable difference in the pulping and bleaching process, (Tripathi et al., 2013). Rice straw is one of the most important raw materials in the future of the pulp and paper industry (Salaheldin et al., 2014). 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.

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Permalink/DOI: http://dx.doi.org/10.14716/ijtech.v6i1.288

Juwono and Subawi (2014) describe the alkaline treatment advantage to remove the ash component from natural rice straws. High ash content is particularly harmful to cutting tools and to chemical recovery systems in the pulp and paper industry. The silica content has been removed simply by an immersion process in a 5% sodium hydroxide solution to obtain de-silicated rice straw. The rice straw pulping is considered competitively to complement the global demand for raw material in paper production. Therefore, the treated rice straw plays an important role in providing raw material in the form of wood and rice straw blend feedstock for the pulp and paper industry.

However, straw pulp as a semi-chemical pulp is used extensively to produce corrugating medium, often mixed with Old Corrugated Container (OCC) fiber. The straw pulp component could be as high as 70 to 80% blended with 30 to 20% of OCC fiber (Jeyasingam, 1998). Recycled paper is one of the important sources of fiber for papermaking. Old corrugated cardboard and old newspapers are the main source of recycled paper in many countries. Fibers in corrugated cardboard and newspapers have different characteristics than virgin wood pulp fibers. This is due to the fact that they were dried then rewetted during the recycling processes. Thus, mechanical and chemical treatment must be carried out so as to make the recycled paper restore its strength and quality. This may also occur by means of fractionation, using chemical additives and mixing recycled pulp with virgin pulp (Hocking et al., 2005; Rahmani et al., 2009). Paper and paperboard are the most widely used materials in food and drink packaging (Song et al., 2000; Triantafyllou et al., 2007). 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 (Rudra et al., 2013). The antifungal activity of chemicals extracted from rice straw on the radial growth rate and the activity of some hydrolyzing enzymes were studied. The rice straw extract had antifungal properties, thus it can be used as a natural alternative approach to synthetic fungicide (Yehia & Saleh, 2012)

The use of shrimp exoskeleton powder to produce antimicrobial activities by chitin against marine and estuarine pathogens has recently received considerable attention as a new source of novel antimicrobial substances (Varadharajan & Ramesh, 2012). Borax is widely used in industry, but it is forbidden as a food additive by various countries due to its high toxicity (Dengbin et al., 2013). Potassium tetraborate and borax ($Na_2B_4O_7$) were evaluated for their in vitro activity against *Fusariumsulphureum* and for their curative and preventive efficacy against postharvest dry rot infections on potato tubers (Yongcai et al., 2012). The antimicrobial activity, minimum inhibitory concentration (MIC) and minimum sterilization concentration of the extracts from cactus were studied (Yang et al., 2005). The results showed that the wild cactus extracts had a strong inhibitory activity against *Escherichia coli* and *Bacillus subtilis*, but the activity of edible cactus (*Opuntia Miloa Alta*) extracts was weak. The aim of the present work is to improve recycled old newsprint pulp properties by blending it with virgin rice straw pulp. Also, the improvement of the antimicrobial activity of paperboard made from blended pulp was studied to achieve an appropriate packaging board.

2. EXPERIMENTAL

2.1. Materials

Rice straw pulp was prepared by cooking rice straw using 5% sodium hydroxide at 80^0C in atmospheric pressure. NaOH, hydrogen peroxide $MgSO_4 \cdot 7H_2O$, borax, shrimp exoskeleton powder and other chemicals were of pure analytical grades and used as received.

2.2. Preparation of Old Newspaper Pulp (ONP)

Type 1: 100 o.d g. (oven dry) newspaper sheets were cut into pieces and immersed in hot water containing 3 wt% NaOH at a liquor ratio of 1:5 for 2 hours at 50°C. After the required time, pulp was mechanically stirred and washed by water till neutrality and finally air dried.

Type 2: 100 o.d. g newspaper sheets were cut into pieces and 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% concentrate 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 until neutrality, followed by acetone 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

2.3. Handmade Paper Sheets Tests

Carton sheets of basis weight 120g/m^2 were made from pulp slurry according to the Tappi-Standard Method using the sheet former of AB Lorentzen (Stockholm, Sweden). Pulp slurry contains rice straw pulp and Type 1 or Type 2 newspaper pulp at the percentages indicated in Table 1.

Table 1 The composition of handmade paperboard sheets

Handmade symbol	Rice straw pulp %	Old newspaper pulp type 1	Old newspaper pulp type 2	Antimicrobial additive, 2%
S1	100	0	0	-
S2	33.3	66.6	0	-
S3	50	50	0	-
S4	0	100	0	-
S5	50	0	50	-
S6	33.3	0	66.6	-
S7	0	0	100	-
S8	50	0	50	Shrimp exoskeletons
S9	50	0	50	borax
S10	50	0	50	Cactus peel extract

The slurries were well-stirred to ensure a uniform distribution of the fibers of the two mixed pulps. The sheets were then placed for conditioning at 65% relative humidity, and at temperatures ranging from 18 to 20^{o}C. The sheets were tested for tensile strength according to the German Standard method by means of a Karl Frank 468 tester (Weinheim–Berkenau) and burst strength according to TAPPI Standard testing method, TAPPI T403. Stiffness was determined using the TABER tester model 150B. Also, Scanning Electron Micrographs (SEM) were taken using the FEI INSPECTS Company, Philips, Holland.

2.4. Antimicrobial Activity

Handmade paper sheets made from 50% rice straw pulp and 50% Type 2 ONP were considered to study the antimicrobial activity of three additives namely, shrimp exoskeleton powder, borax and cactus peel extract. This selection for a handmade sample is due to its higher tensile strength. Each additive at 2% based on oven dry pulp weight was added to the pulp mixture and stirred for 24 hours before papermaking. Paperboard samples containing these additives were given numbers S8, S9, and S10 respectively, as shown in Table 1. Their ability to inhibit the

growth of Gram-positive and Gram-negative bacteria, yeasts and filamentous fungi was observed using an overlay method (Williams et al., 1983).

Antimicrobial assay:

Strains used:

Common pathogenic and food spoilage microorganisms were selected for their relevance in bakery products and other food, namely gram-positive bacteria; *Bacillus subtilis* and 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 on Sabaroud's agar medium (Lab M., Bury, Lancashire, UK) and fungi were slanted 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 in plates for the bioassay of gram positive and gram negative bacteria.

Bioassay:

The antibacterial screening was essentially detected by the disk diffusion agar method described by Moosdeen et al. (1988). The organisms were streaked in radial patterns on the agar plates. Plates were incubated under aerobic conditions at 37°C and 28°C for 24-hour and 48-hour periods 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 in triplicate. Plates were examined for evidence of antimicrobial activities, represented by a zone of inhibition of the microorganism's growth around the paper disk and diameters of clear zones were expressed in millimeters (mm).

3. RESULTS AND DISCUSSION

3.1. Unblended Paperboard Properties

Rice straw was used as an alternative raw material to obtain cellulosic pulps. In this study pulping was made by using classic reagents such as soda. The properties of the paperboard made from rice straw soda pulp alone or recycled ONP are shown in Table 2, Figure 1 and Figure 2. Compared to rice straw pulp, fibers of recycled pulp are more easily compressed into the voids of the sheet, indicating flexibility; however, rice straw fibers are stiffer and not so easily compressible. This may be attributed to the high silica content in the pulp. Pulping conditions, applied in this study, did not reduce silica content. Recycled Type 1 and Type 2 ONP had tensile strengths higher than that of rice straw pulp because ONP originally contains chemical pulp.

Table 2 Mechanical Properties of paperboard from unblended /blended rice straw pulp and recycled old newspaper pulp

Handmade symbol	Stiffness (Kg.cm)	Burst (Kg/cm^2)
S1	25	0.58
S2	25	0.56
S3	20	0.53
S4	20	0.61
S5	20	0.97
S6	25	1.12
S7	20	1.15

Moreover, in the deinking step, lignin and various extracts, namely the colored substances, were dissolved or modified, leaving behind only white cellulose (McGinnis & Shafizadeh, 1980).Also, Table 1 indicates that burst strength of soda rice straw pulp (0.58 Kg/cm^2) is lower than that of ONP deinked by hydrogen peroxide (1.15 Kg/cm^2).

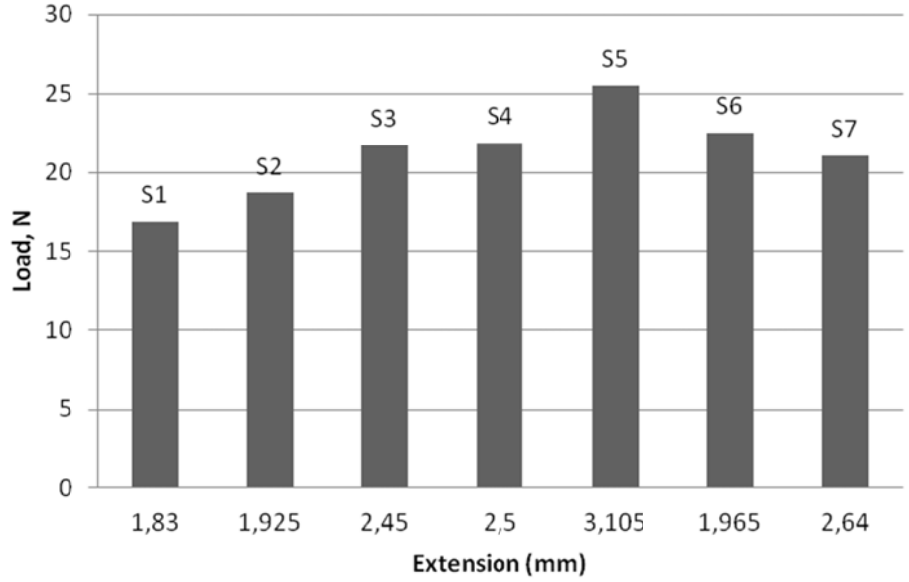


Figure 1 Load-extension curves for rice straw pulp blended with ONP pulp

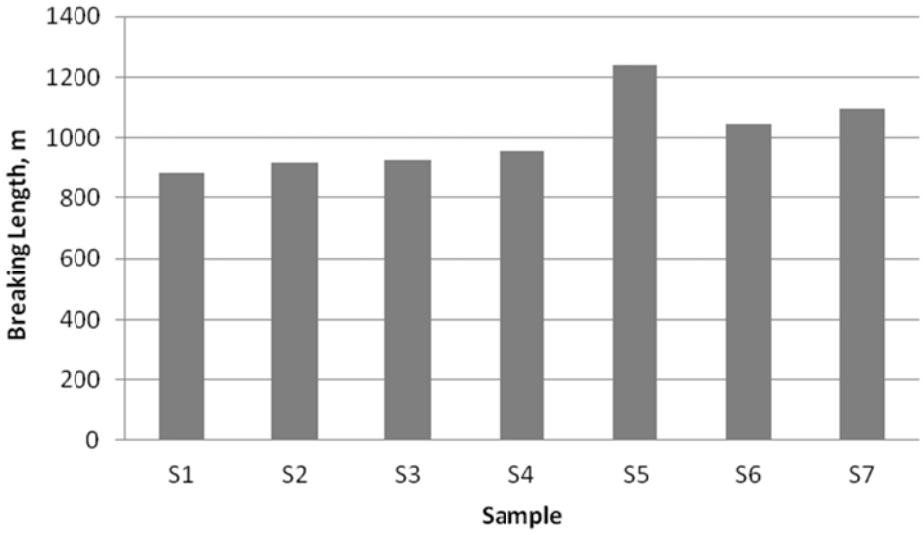


Figure 2 The influence of blending rice straw pulp with ONP pulp on the breaking length of handmade paperboard sheets

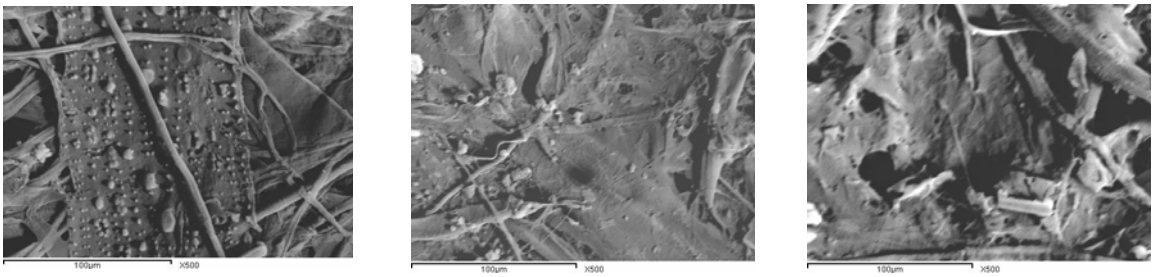
3.2. Blended Paperboard Properties

Since the mechanical properties of rice straw pulp are weak due to the high silica content, blending with deinked recycled ONP is considered an economical way to improve its properties. The properties of the paperboard made from mixtures of the rice straw soda pulp and recycled ONP are shown in Table 2. The paperboard properties were greatly affected by the incorporated rice straw pulp. The change depends on the percentage of blending and the type of recycled paper used (Ibrahim, 2003). 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 Figure 2. This is due to flexibility of ONP pulp and the presence of short fragments in the straw pulp producing a highly bonded structure. Thus, the virgin nature of rice straw pulp improved the structural and mechanical properties of the blend. Among these blends, 50/50 ONP type 2 had the best tensile strength more than other blends. Pulp composed of 33.3% rice straw pulp + the 66.6 Type 2 ONP blend sample had better burst strength and stiffness than 50/50 Type 1 ONP and 50/50 Type 2 ONP. Stiffness and strength are two basic paperboard properties which have a major influence on the mechanical 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 fibers used. Due to the different treatment of wood in the mechanical and chemical processes, the resulting properties of the two types of fiber differ considerably. When a paper product is recycled, the re-pulped fibers still ultimately originate from the same two sources, i.e. mechanical and chemical fibers. During recycling, the fibers become contaminated and worn (lose strength). Therefore, primary fibers 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 fibers were used. Beating has created internal and external fibrillation of the fibers. This in turn created more bonded areas in the blended hand sheets. It was also observed that the weak rice straw pulp was modified by blending with recycled ONP.

3.3. Scanning Electron Microscopy

The modification of rice straw fibers was visually evaluated by Scanning Electron Microscopy (SEM). It was observed that the addition of the flexible Type 2 ONP pulp seemed to fill up the voids in the sheet and created more bonding with rice straw fibers (Figure 3b).



(a) (b) (c)

Figure 3 Scanning electron micrographs of the surface of hand sheets of: (a) 50% rice straw pulp + 50% Type 1 ONP; (b) 50% rice straw pulp + 50% Type 2 ONP pulp; (c) Type 2 ONP

Figure 3a depicts the surface structure of 50% rice straw pulp + 50% Type 1 ONP, Figure 3b illustrates the addition of 50% rice straw pulp to 50% Type 2 ONP pulp, while Figure 3c shows the Type 2 ONP fibers which contain more voids. This is in agreement with the results of mechanical tests which indicate the improvement of rice straw soda pulp when blended with deinked old newspaper.

3.4. Antimicrobial Activity of Blended Paperboard

Bacillus subtilis

The results in Figure 4 showed that: samples Nos. S1, S2, S3, S6 and S7 showed a strong inhibitory effect, while a moderate inhibitory effect was observed using sample No. S5. On the other hand, a weak inhibitory effect was noticed from S4, S6 and S9.

Escherichia coli

The results in Figure 5 showed that most of the samples had a moderate inhibitory effect, while a weak inhibitory effect was observed from S5, S9 and S10.

Candida albicans

The results illustrated in Figure 6 indicated that a weak inhibitory effect was determined from S5, S9 and S10. Furthermore, the rest of the samples showed a moderate effect.

Asperagillus niger

The results in Figure 7 showed that most of the samples had not any inhibitory effect with the exception of S1 and S2 which had a strong effect and S3 which had a moderate effect.

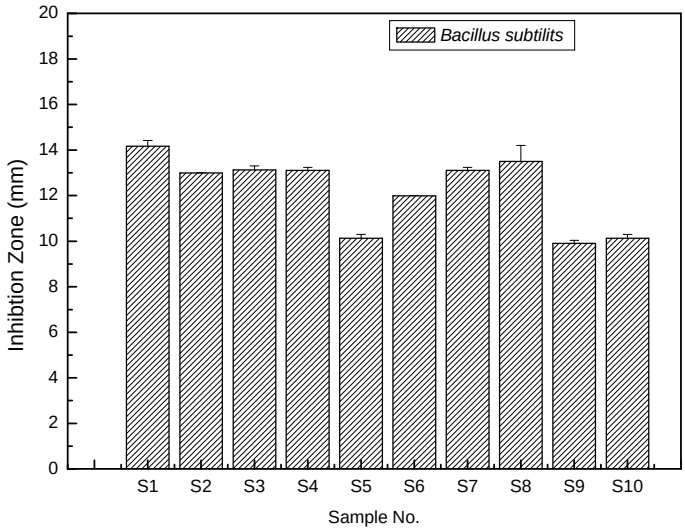


Figure 4 The antimibacterial activity of the paperboard made from rice straw pulp and the ONP pulp blend against *Bacillus subtilis*

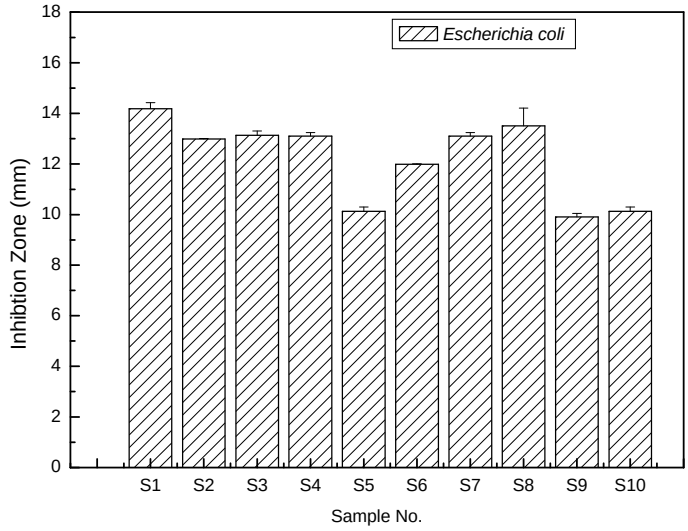


Figure 5 The antibacterial activity of the paperboard made from rice straw pulp and the ONP pulp blend against *Escherichia coli*

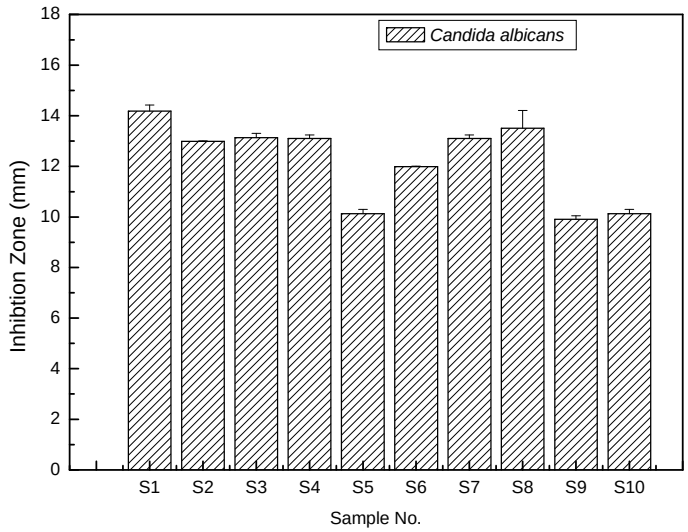


Figure 6 The antifungal activity of the paperboard made from rice straw pulp and the ONP pulp blend against *Candida albicans*

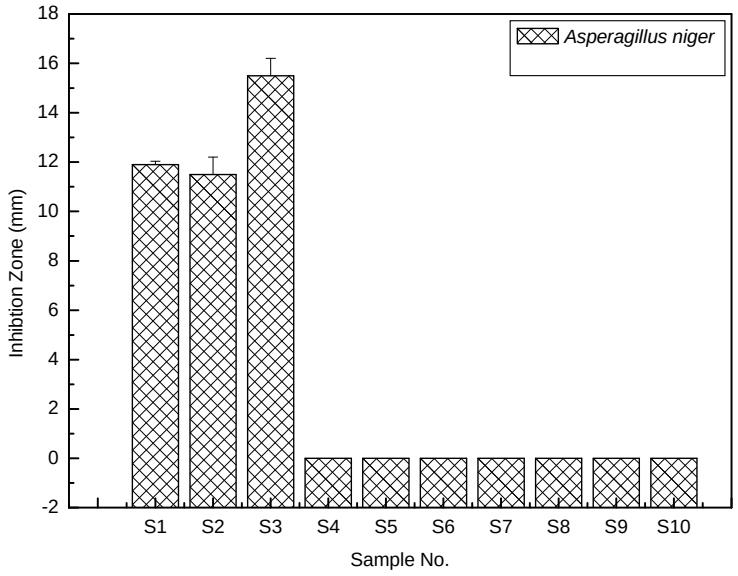


Figure 7 The antifungal activity of the paperboard made from rice straw pulp and the ONP pulp blend against *Asperagillus niger*

4. CONCLUSION

ONP was re-pulped by two methods using sodium hydroxide and commercial hydrogen peroxide and blended with rice straw pulp. Recycled Type 1 and Type 2 ONP had tensile strengths higher than rice straw pulp, because ONP originally contains chemical pulp. The paperboard properties made from the two blended pulps were greatly affected by the incorporated rice straw pulp, with the changes dependent on 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 Type 2 ONP had the best tensile strength more than other blends. Shrimp exoskeleton powder, borax and cactus peel extract were added to paperboard made from 50% rice straw pulp + 50% Type 2 ONP by 2% based on oven dry weight pulp as antimicrobial agents. Samples S1 to S3 had a moderate antibacterial activity on most of the pathogenic microorganisms used, such as *Bacillus subtilis*, *Escherichia coli*, *Candida albicans* and *Asperagillus niger*, except for S3, which had a strong inhibitory activity against *Asperagillus niger*.

5. ACKNOWLEDGEMENT

The authors would like to acknowledge support from the Foundation (No.10130101) of National Research Centre, Egypt.

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