Development of Silver Nanoparticles Incorporated Antimicrobial Food Packaging Paper Derived from Corn Cob

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Abstract— *Food packaging material was developed from corn cob pulp that is a potential source of non-wood fibre. Corn cob was soaked in 6% NaOH solution in the ratio of (1:6) that is 1 part grain less corn cob and 6 part NaOH solution. Alkali treatment disrupts cell-wall by dissolving hemicellulose, lignin and silica by hydrolyzing uronic and acetic acid esters and by swelling cellulose. After 24 hours the soaked mixture was taken and cooking was done at temperature of 120^{o}C for 80 minute till gel like structure form and corn cob give paste and soapy texture like structure. After cooling washing was done to remove waste liquor that was followed by pulping to make paper.Studies have focused on developing food packaging material that is paper incorporated with silver nanoparticles in the ratio of10 mg per 100 ml of pulp. Developed paper has significantly reduced the presence of E.coli and Bacillus subtilis in wrapped food sample. The resulting pulp from corn cob was used for paper making and the papers obtained were tested for their mechanical properties; grammage (81) g/m^{2}, thickness (0.199) mm, stiffness (65-70) Taber, tearing strength (MD 39, CD 41) mN for paper incorporated with AgNPs.*

Overall, antimicrobial packaging shows promise as an effective method for the inhibition of certain bacteria in foods, but barriers to their commercial implementation continue to exist.

Keywords— AgNPs, Antimicrobial packaging, Bacillus subtilis, Corn cob, E. coli, Paper, Pulp.

I. INTRODUCTION

The conventional paper is derived from wood that is the paper industry is mainly depending upon forest resources, as a result deforestation take place to meet the availability of raw material for paper making industry. It is broadly accepted that the deforestation causes environmental pollutions and global warming. In recent year, people have placed a high emphasis on forest preservation and rational use of forestry and agriculture residues.Wood is the major raw material for the global pulp and paper industry. Some non-woods are still used, however, especially in China and other Asian countries. At the present time, the most common non-wood fibre is straw. This material accounts for 46 percent of total production, followed by bagasse (14 percent) and bamboo (6 percent). Other non-wood fibres, such as cotton, hemp, sisal, and kenaf, are also becoming more important in the manufacture of pulp and paper **(Atchison, 1995).** New developments in food packaging materials have been recently implemented by the increase in consumers demand for minimally processed foods and stricter requirements regarding consumer health and safety. In fact, new technologies are being investigated in this research line, such as modified atmosphere packaging and active packaging technologies **(Suppakul*et al.* 2003).** Silver nanoparticles have been used extensively as antimicrobial agents in health industry, food storage, textile coatings and a number of environmental applications. Antimicrobial properties of silver nanoparticles caused the use of these nano-metals in different fields of medicine, various industries, animal husbandry, packaging, accessories, cosmetics, health and military. For instance, it was shown that silver nanoparticles mainly in the range of 1-10 nm attached to the surface of *E. coli* cell membrane, and disturbed its proper function such as respiration and permeability **(Cho *et al.* 2005).**There has been a cyclic trend in the production of pulp and paper, alternating between the non-wood and the wood materials. Originally paper was

being made from non-wood materials such as papyrus, hemp and textile rags. With the development of technologies for isolating pulp from wood, it resulted in abandoning paper making from many non-wood materials. Since then, it has been cheaper to produce pulp and paper from wood. However, to date the trend is reversing from wood as the major source of pulp for paper making to non-wood materials such as agricultural food crop residues, grasses, shed tree leaves, fibrous shells of fruits and others.

This is due to the fact that the supply of wood for pulp is decreasing as a result of deforestation in most part of world, more especially in Uganda while the non-wood materials are more available and can readily be regenerated after a short period **(Kamoga*et al.* 2013).**Thus the use of corn cob for pulp and paper production and incorporation of silver nanoparticles for antimicrobial properties of paper is investigated in this study.

II. METHODOLOGY

2.1 Materials, reagents, strains:

Fresh samples of corn were collected from local vegetable market of Allahabad. It was cleaned to remove sand or soil after that raw material was stored at room temperature in dark to avoid moisture evaporation.Orange peel was purchased from local vendor and washed with normal water to remove dust particles then made peeling with hand and cut the peel in small size of 1- 2 cm.

Fig. 1: Sample of chipped corn cob

Silver nitrate (Qualigens Fine Chemicals, Navi Mumbai), Sodium hydroxide pellets (RFCL Ltd., Gujrat, India), Sulphuric acid (RANKEM).Antibiotic Ampicillin disc (Himedia). All the chemicals used in present study wereof analytical grade commercially available.The*E. coli* and *Bacillus subtilis*cells used in the present study were collected from Department of Microbiology & Fermentation Technology, SHIATS (Allahabad, India).

2.2 Silver nanoparticle synthesis:

For synthesis of silver nanoparticles 50 ml of silver nitrate solution of 1 mM concentration was taken in a conical flask and added 5 ml of orange peel extract to above. Then stirred it in magnetic stirrer (MicrotechMedicraft) at 60℃ and observed that after 5 min. color has been changed to light yellow then after some time changed to dark yellow which indicated formation of silver nanoparticles that was confirmed using UV-Vis spectrophotometer.

2.3 Development of antimicrobial paper using grain less corn cob pulp:

Grain less corn cobs (GLCC) was chopped into small pieces (1-2 cm) with sharp knife and collected 181.2gm. These pieces were placed in hot air oven (MicrotechMedicraft, Model- ATC-222) to dry at 40^{o}C for 20 hours (or) may take Sundry for 24 hours depending upon the facilities. After drying GLCC has been found to be 61.7 gm.

To degrade the lignin from the GLCC, 6% NaOH solution (RANKEM, Grade –AR) has been prepared. To prepare the solution, 60 grams of sodium hydroxide pellets were dissolved slowly in 1000 ml distill water at room temperature. 1 molar H_2SO_4 was prepared to add during pulping for pH adjustment. The 500ml volume beaker was taken in which dry chopped cob pieces were taken and 6 % NaOH was added in the ratio of (1:6) i.e. one part dry GLCC and six part sodium hydroxide solution. The complete mixer was kept at room temperature for 24 hours for soaking. After 24 hours the soaked mixture was taken and cooking was done at temperature of 120^{o}C for 80 minutes using hot air oven (MicrotechMedicraft) till gel like structure form and GLCC form paste and soapy texture like structure.After cooling the paste at room temp. was washed with tap water and filter by using old carry bag made of cellulosic material and fibre was collected and minced in mixer for one minute to form fine consistency solution, now pulp ready for using in paper moulding.The volume of 100ml pulp was mixed with 10% of filler and 10mg silver nanoparticles solution. The solution was stirred for 1 hour on magnetic stirrer (MicrotechMedicraft) for uniform mixing. Then solution was poured in tray which holds only pulp. Paper sheets were formed using a handmade paper mould and deckle. Then it was kept for 10 hours at room temperature in dark. Pressing was done by keeping 2 blocks of tiles nearly 2-3 kg. Then it is removed after 5 hours and paper was dried at 35^{0}C for 8 hours while keeping paper in between board, to avoid shrinkage.

(a)

(b)

Fig. 2: (a) Unbleached corn cob pulp (b) Waste liquor

Fig. 3: Developed antimicrobial paper

2.4 Preparation of media for microbial growth:

For culturing of *Bacillus* and *E.coli* bacteria, Nutrient Agar (RANKEM, AR grade) was prepared and sterilized in autoclave. The culture used for testing was revived in nutrient broth and kept for 12hours in shaker incubator before use. Sample from paper were taken and cut into small disc shaped and UV treated for 10 minutes to avoid any microbes due to handling. For reference Antibiotic Ampicillin disc (Himedia) was taken. Plates were swabbed with *Bacillussubtilis* and *E.coli* with concentration of 0.01 at 600nm using UV-Vis. Spectrophotometer (Microtechvenus). Disc were spotted and kept at 37^{o} C for 24 hours in incubator.

2.5 Paper Characterization:

2.5.1 Testing of tearing strength

Tearing strength of paper was determined by Tearing Strength Tester (Emeldorf Type) (Techno-India).

2.5.2 Testing stiffness

Stiffness of paper was determined by Stiffness Tester (Taber Type) (Techno India, Roorkee, U.K., Model-TI/TS/ED/126).

2.5.3 Grammage Testing

It also called density of the paper. Sample with equal dimension of 5*5 cm^2 was taken in triplicate and each was weigh.

Formula:

Grammage = weight of the sample paper/area of the sample paper (g/m^2)

2.5.4 Thickness Testing

Thickness of the paper was measured using digimatic micrometer (Mitutoyo Corporation, Model-293-821) with range of 0 to 25 mm+/- 0.0001 accuracy.

III. RESULT AND DISCUSSION

3.1 Development of antimicrobial paper:

Paper intended for packaging of food materials has been developed by taking the fibre from non-wood agro waste material i.e. grain less corn cob pulp.

The pH of the pulp maintained near or little above the value of 7. This helps in stabilizing the silver nanoparticles adding in the pulp. To increase the strength of the paper filler pulp (waste paper) is mixed at 10% ratio. The developed paper is observed to be light yellowish, since there are no bleaching agents are added in pulp.Silver nanoparticles incorporated paper has slightly yellowish color compared to normal paperas it was not bleached. Color of the paper was found light yellow below pH 7 and color darkens as pH rises above 7, it was observed dark yellowish.

Table 1: Physico-chemical parameters of developed paper from corn cob pulp

Parameters	**Normal Paper**	**Cob derived paper**
Thickness	0.111mm	0.199 mm
Grammage	75 g/m^2	81 g/m^2
Tearing Strength	MD 38 , CD 42mN	MD 39 , CD 41mN
Stiffness (bending)	52-60 Taber (avg.)	65-70 Taber (avg.)
Appearance	White	Yellowish to Brownish
Bleaching	Yes	No
Smoothness	Smooth	Less smooth
pH	7.2	7.4

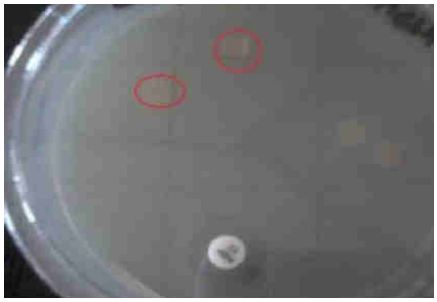
3.2 Antimicrobial activity of the paper:

The antimicrobial property of the developed paper was completed by antibiotic disc diffusion method. The samples were taken in duplicates and small disc were prepared and treated with ultra violet light for 20 minutes as to avoid any fungal or other microbial attached to surface while handling. The two strains were selected i.e. *E.coli* and *Bacillussubtilis*and studied for antimicrobial property. The result was positive for *E.coli*for different amount of silver

nanoparticles solution tested i.e. 2, 4, and 8 mg.These showed clear zone of inhibition. As shown in Fig.4, But the result was negative for *Bacillus subtilis*. 10mg silver nanoparticles incorporation showed positive result for both gram positive and negative strain. As shown in Fig.5.These are common bacteria in food products.

E.coli(gram negative)*Bacillus subtilis*(gram +)

Fig. 4: Samples containing 2 mg of silver nanoparticles per 100 ml of pulp slurry showing zone of inhibition



E. coli (gram negative)

Bacillussubtilis (gram +)

Fig.5:Samples containing 10 mg of silver nanoparticles per 100 ml of pulp slurry showing zone of inhibition with E.coli and Bacillus subtilis

The antimicrobial activity of the silver nanoparticles towards *E.coli* was found to be more sensitive, as very less quantity of silver nanoparticles (4mg/100ml pulp) showed the formation of zone of inhibition. While gram positive *Bacillus subtilis* was resistant at concentration of (4 mg/100ml pulp), it showed zone of inhibition at higher concentration (10 mg/100 ml pulp).So for the development of antimicrobial paper 10 mg of silver nanoparticles was used which showed clear zone of inhibition.

IV. CONCLUSION

The results obtained from this study have shown that corn cob is suitable non wood raw material for papermaking. The study shows the utilization agro waste material like corn cob. The physical properties like grammage, tearing strength, bending etc. were found to be nearly equal to normal paper. The antimicrobial activity was found positive for both gram negative and positive with concentration of 10 mg in 100gm of pulp solution.Thus, we concluded that the developed packaging material incorporated with silver nanoparticles gave good response for their antimicrobial purpose.

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