IN VITRO STUDY OF BIOCERAMICS-WOVEN COTTON FABRIC COMPOSITE AS SLOW DRUG DELIVERY DEVICE FOR BIOMEDICAL APPLICATIONS

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ABSTRACT

Recently the use of textiles in medical applications has gone far enough for treatment and health care purposes. Biopolymers and other biomaterials can be used together to develop wide range of materials including composites to serve the intended use. The most promising advantages to be used in this area is biocompatibility i.e. their non-toxicity in biological systems when applied internally, and far enough their comfortability and flexibility with better performance. This may be compared with derived petrochemical materials which have side effects to biological systems and further their complexity in handling including disposability.

The most promising advantages of controlled drug release devices are; drug is released at specific target, decrease drug concentration, reduce drug morphology change due to biotransformation and releasing drug at specific rate for a specified period of use.

This study focused at developing and characterizing bioceramics-woven cotton fabric PLA reinforced composite as a drug delivery device for biomedical application. The cotton woven fabric of different pore sizes, (0.5 mm), (1 mm), and (1.5 mm) were developed using cotton yarn of count 30 Tex in handloom machine. Bioceramic particles were loaded with antibiotic (streptomycin sulfate) by using rotor vapor evaporator and followed by embediment of loaded particles into the fabrics. Then, composites were developed by dipping the embedded fabrics into the PLA solutions of different concentrations: 0.01mg/ml, 0.03mg/ml and 0.06mg/ml. The developed composites were characterized in terms of mechanical and physical properties.

The results showed that tensile strength varied proportional to the pore sizes of the fabric and concentration of polymer solution i.e. the lower the pore size the higher the mechanical strength and the higher the concentration of polymer the higher the mechanical strength. Dissolution study showed that, when pore size kept constant, drug release rate was decreased when polymer concentration was increased, this result suggested that the release rate is influenced by the polymer concentration. Degradation study showed that the composites was degraded by 2.33%, 4%, and 7.33% for 0.5 mm pore size specimen for 0.01g/ml, 0.03g/ml and 0.06g/ml concentration respectively after two weeks. Absorption study showed that at higher concentration of polymer only small amount of water could be absorbed by the composite. It was then concluded that, the developed composite can be used as drug delivery device for wound dressing application.

Keywords Words: *Bioceramics, antibiotic, Woven fabric, biodegradable polymer, Bioceramics-woven cotton composite, drug delivery device, wound dress.*

1.0 INTRODUCTION

Drug delivery systems (DDSs) are the most promising applications for human health care and represent an ever-evolving field for biomedical biomaterial science (Yoo *et al*., 2006). Wound dressing can be developed with such a system so that while preventing bacterial growth and infections by delivering antibiotic it enhance tissue growth on the other hand. Advantages DDSs have over the other methods of wound treatment are drug is delivered at specific target, reduce drug concentration in the body which have adverse effect in the body, minimize drug morphology change when enter in the blood stream due to biotransformation which in turn may reduce drug ability to heal the specific target and drug is released at specified rate for specific period of use. There is wide range of materials used to develop DDSs that includes biopolymers, biomaterials and composites of combination of both biopolymer and biomaterials or with textile materials.

2.0 METHODS AND MATERIAL

2.1 Materials

Polylactic acid (PLA) 3052D (specific gravity = 1.24, Tg = 55–60 °C, MP = 200 °C) with Mw = 75,000 (g/mol) was obtained from Nature Works LLC Australia. Chloroform NaOCl were obtained from local supplier, streptomycin sulfate was fairly donated by Micro-Biology Department, University of Dar es Salaam, cotton yarn was also donated fairly by Mr. Amos, Bantu Kikoi Company.

2.2 Methods

2.2.1 Woven fabric preparation

Woven fabric was developed in handloom using 30 text cotton yarn, in order to produce 0.5 mm pore size, the distance from one head wire to another in head frame was set 0.5mm. . The other pore sizes 1mm and 1.5mm were developed by pulling out yarn from the 0.5mm pore size fabric. After development bleaching with 20% NaOCl was done in a well cleaned bath and rinsed with distilled water then dried in air for 3 days.

2.2.2 Bioceramics preparation

Ceramic particles were prepared from the conversion of coral stone obtained from Indian Ocean around Dar es Salaam which is rich in calcium carbonate and the conversion was assisted by ammonium dihydrogen phosphates, firstly coral were crushed to reduce the size by hammer and ground by bowl milling machine for about 6-7 hrs. The ground particles were then converted to hydroxyapatite by ammonium dihydrogen phosphates, rinsed by distilled water and then dried in oven for one night.

2.2.3 Bioceramics-woven cotton PLA reinforced composite development

The bioceramics-cotton PLA reinforced composite was developed by solution casting method, adapted from (Macha *et al*., 2015). Firstly PLA polymer was dissolved in chloroform, in 600ml beaker 500ml of chloroform was poured and placed in hotplate at 60˚C with the help of magnetic stirrer it took 40-50min to dissolve completely. Then the embedded fabric was placed on top of aluminum foil in the bath and PLA solution was poured, all these work performed in fume chamber because of the effect of the fumes of chloroform. The prepared

composites were stored in dissector for further characterization.

2.2.4 Physical and mechanical characterization

Physical properties of oven fabric such as weight, fabric density, warp and weft space, cover factor were measured using appropriate instruments in the Laboratory and appropriate calculations based on literature review were carried out accordingly. Mechanical properties of woven fabric and developed composites were measured at Tanzania Bureau of Standards (TBS) according to TBS standard TZS 22:1979 (1st Ed), titled "Textiles-Woven fabrics-Determination of breaking load and extension."

Tests were carried out in a universal tensile testing machine (Equipment) type: Instron 5566, Series IX Automated Materials Testing System 8.25.00 with the Crosshead Speed 100mm/min and the load cell is 10kN samples were cut to 5×10 cm, and with the help of blue hill software the tenacity, strain and stuffiness properties were given.

2.2.5 Drug loading and dissolution study

Drug was loaded in bioceramic particles in which 10% of drug was loaded. 5g of particles were loaded with 500mg of streptomycinsulfate antibiotic. Method used was simply dissolve the antibiotic in 100ml of distilled water in a round bottomed flask, particles were put in the same flask and allowed water to evaporate in a rotary evaporator. It took 30 minutes for all the water to evaporate from the flask.

Dissolution was studied by allowing drug to dissolve in solution of PBS for at least two weeks and 2ml of sample of PBS was taken every day and measured the absorption properties. The measured samples were calculated for the drug release from the established linear relationship between the absorption and concentration of streptomycin at max λ= 495 nm.

2.2.6 Biodegradation study

This was studied by monitoring weight loss under SINK condition in PBS at 7.4 in water bath shaker set at 37˚C. Note that PBS is the solution which assimilates human body fluid. After 18 days all the samples were completely dissolved. Biodegradability was measured as the difference between the weight before dipping in the PBS solution and after complete dissolve of the composite in the PBS.

2.2.7 Water absorption study

Water absorption was studied by monitoring weight gain, the weights of 4×4cm samples were measured, then dipped in distilled water for 1hr and then measured the weights again. The differences between the two were taken as water absorption capacity.

3.0 RESULTS AND DISCUSSION

As reinforcement in the composite, the measurement of mechanical strength of woven fabric has become a crucial role.

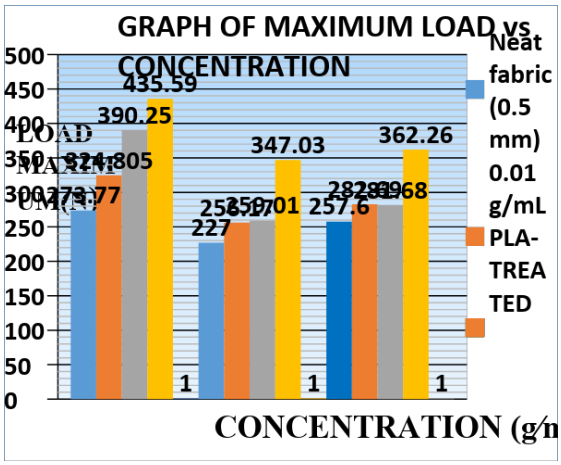


Figure 1: The mechanical properties of woven and composite load vs. polymer concentration.

The mechanical properties of woven and composite load against concentration are presented in Figure 1.The mechanical properties decreased as pore size increased since the number of yarns were decreased as pore size increased. This

effect has also been observed in physical properties of fabric where fabric weight and cover factor were decreased as pore size increased since as some number of yarns decreased their contribution to properties of fabric reduces too. Degradation study shown that high amount of polymer was degraded for high concentration composites, about 2.33%, 4% and 7.33% for 0.01g/ml, 0.03g/ml and 0.06g/ml respectively as shown in Figure 2. It took 18 days for the composite to completely degrade, this means in order for composite to degrade below this duration lower polymer concentration must be used. Water absorption study is presented in Figure 3 which shows that as polymer concentration increased in the composite the water absorbing capacity decreased. This is true since, polymer used is hydrophobic in nature it absorbs little amount of water the effect which is increased when concentration is increased.

Figure 4 shows the results obtained from dissolution study. The rate of dissolution is explained as percentage drug release (PDR %)

PDR% = (amount released (mg)/ Total amount drug initially loaded) × 100% where when keeping pore size constant and change concentration the high amount percent was released at lower polymer concentration, this can be explained by the effect of polymer with higher concentration takes longer time to degrade than the lower note that the major drug dissolution involved is polymer degradation which is affected by polymer concentration.

It was also shown that in controlled release, the physical and chemical properties of the system are modified to achieve the drug release kinetics. The main factors involved in achieving the desired release rates are; Desorption of the surface bound/adsorbed drug, diffusion through nanoparticles matrix, diffusion through the polymer wall and combined erosion/diffusion process.

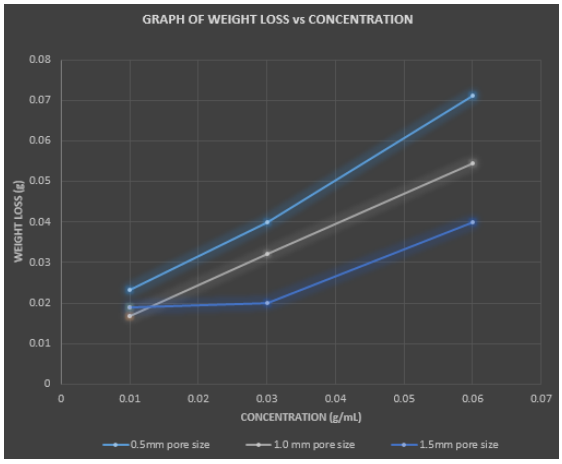


Figure 2: Weight loss vs. concentration during degradation

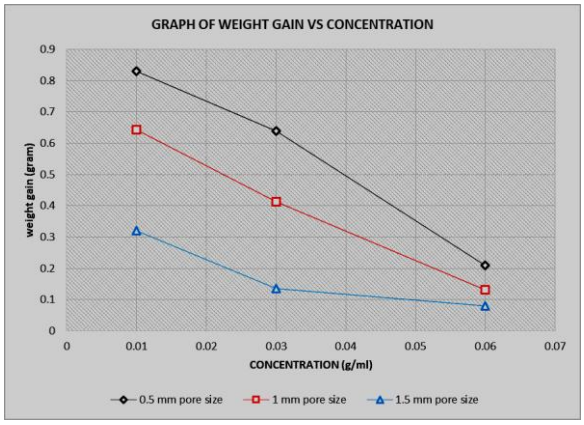


Figure 3: Weight gain vs. concentration during water absorption study.

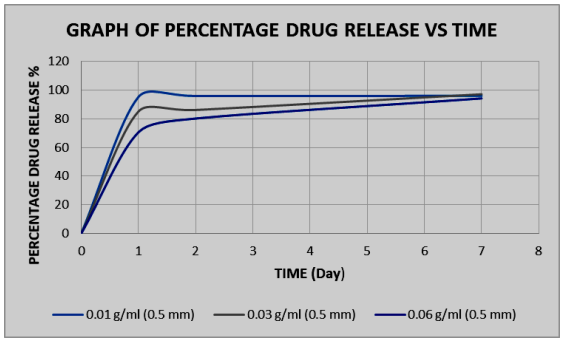


Figure 4 Percentage drug release vs. time as studied from dissolution study.

Also the influence of pore size to percentage drug release was studied as shown in Figures 5, 6 and 7.

As depicted from the graph of PDR against time for 0.06 g/ml (sample) the maximum release was found during the seven day, while for the graph of PDR against time for 0.06 g/ml (1mm) the maximum release was found during the eleventh day and for that of 0.06 g/ml (1.5 mm) has shown maximum release during the twelfth day, from this results we then concluded that when keeping constant pore size and changing concentration the drug release rate is reduced when the pore size increases. This phenomena can be explained as for those bigger pore sizes more polymer was taken and hence has contributed to low drug release rate.

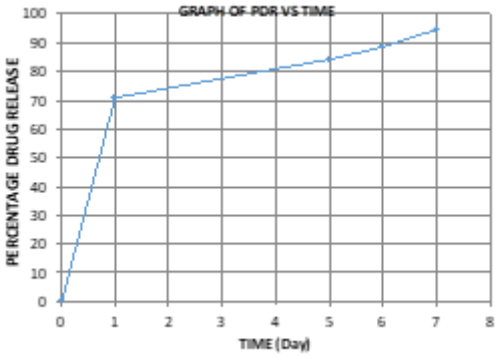


Figure 5PDR vs. time for 0.06g/ml (0.5mm pore size)

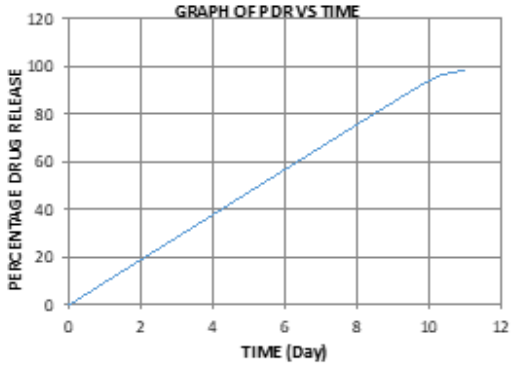
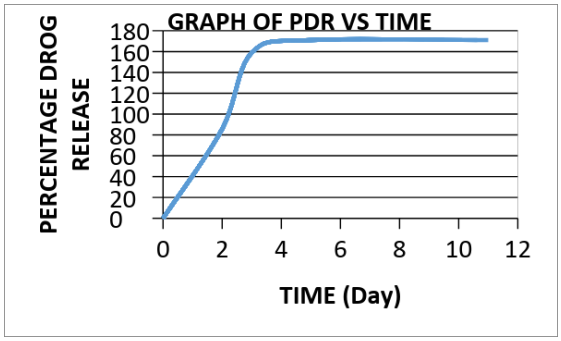


Figure 6 PDR vs. time for 0.06g/ml (1mm pore size)



4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Cotton fabric - PLA composites were successfully developed by simple methods: solution casting as adapted from (Macha *et al*., 2015). The woven fabric which was used as reinforcement was successfully developed by hand weaving technique in handloom machine. Although the pore size of the fabric were rectangular due to yarn being pulled in one direction but for the purpose of intended use has shown good results. Also as expected from the theory that higher amount of polymer causes low degradation this has been proved from the degradation test by considering weight loss against of the composites against concentration for 18 days and the results were positive. Dissolution study was conducted in well controlled manner to achieve the studying goals but only results of few days have shown good results this is due to insignificant preparation of the test and the instrumentation error. Also it was observed that the results in dissolution study were not good for the pore size 1.5 mm. It was also shown that mechanical strength of the developed composites were successfully increased, this was performed by mechanical testing using instron machine at TBS.

4.2 RECOMMENDATIONS

The composite developed showed good features; mechanical properties, degradation properties, and dissolution rate. The small deviation from the true and expected results has been contributed to number of reasons such as; the pore sizes of woven fabric developed were not square and the pulling out of yarns was performed in one direction and hence lack of fabric uniformity, also there was instrumentation problems for testing equipments, such as power problems and longer time auto-zero. However for the intended use of the composite it was successfully developed and used as drug delivery device.

REFERENCES

1. Bret D. Ulery, Lakshmi S. Nair, Cato T. Laurencin: biomedical applications of biodegradable polymers, 2011.
2. Calvin wooding: Regenerated cellulose fibres, 2001
3. Chung D.D.L; Composite materials for biomedical applications. In: Composite Materials. Engineering Materials and Processes. (2003) Springer, London.
4. F.K., G.W.: Textile Preforming. In: Peters S.T. Handbook of Composites.1998.
5. Guo L, Huang M, Zhang X. Effects of sintering temperature on structure of hydroxyapatite studied with Rietveld method. Journal of Materials Science: Materials in Medicine. 2003.
6. Gupta, B Revagade and N, Hilborn, J; poly (lactic acid) fiber: an overview Prog polymer science, 2007.
7. Hench, L.L. Bioceramics. J. Am. Ceram. Soc.1998.
8. Http//www.textilefashionstudy.com/ cotton-fiber-physical-and-chemical-properties-of-cotton, retrieved 2017.
9. Http://www.acmanet.org/composites /what-are-composites, retrieved 2018.
10. Ines, Jose Seabra and Maria, Helena Gil; Brazilian Journal of Pharmaceutical Sciences, vol. 43, 2007.
11. Innocent J. Macha, Medard M. Muna, Josephat L. Magere, Journal of Drug Delivery Science and Technology, Vol: 43, 2018.
12. Macha, I.J., Ben-Nissan, B., Santos, J., Cazalbou, S. and Milthorpe,B.,"Hydroxyapatite/PLA Biocomposite Thin Films for Slow Drug Delivery of Antibiotics for the Treatment of Bone and Implant-Related Infections", Key Engineering Materials, Vol. 696, 2015.
13. J. Biagiotti, D. Puglia & Jose M. Kenny: Journal of Natural Fibers Vol. 1, Issue no. 2, 2004.
14. J. Chevalier and L. Gremillardnd; Journal of the European Ceramic Society 29 (2009).
15. J.S. Bergstrom, D. Hayman, Annals of Biomedical Engineering (2016).
16. Kalita SJ, Bhardwaj A, Bhatt HA. Nanocrystalline calcium phosphate ceramics in biomedical engineering. Materials Science and Engineering: C. 2007.
17. Kantharia N, Naik S, Apte S, Kheur M, Kheur S, Kale B. Nano-hydroxyapatite and its contemporary applications. J Dent Res Science Develop. 2014.