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Evaluation of Abrasion, Biocompatibility and Degradation Behavior of Polypropylene/Sugarcane Bagasse Ash Particulate Composites for Dental Application

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Abstract

This study reports abrasion, biocompatibility and degradation behavior of Polypropylene (PP)/Sugarcane Bagasse Ash Particulate (SBAP) composites for possible application as dental implant materials. PP composites were prepared with varying weight per cent of SBAP ranging from 10 – 50 wt% at regular interval of 10. Hardness test and wear analysis were conducted. Degradation test was performed using different media, namely artificial human saliva (AHS), artificial human saliva with sodium floride (ASSF) and Hank's balanced salt solution (HBSS). Biocompatibility test was conducted using different sex of rats by varying dose injected into their mouth. Results reveal an increase in hardness values and wear resistance with the filler loading. Additionally, the degradation rate of the composites decreases averagely with the filler addition. It was deduced from the results that the composites are biocompatible and non-toxic. Therefore, PP/SBAP composites would be compatible to human body. Hence, the composites could be recommended to be used as dental restorative materials.

Keywords: Dental implant, Sugarcane bagasse ash particulate (SBAP), Wear rate, Degradation, Polypropylene (PP), Biocompatibility.

1. INTRODUCTION

Naturally occurring minerals and metals such as gemstones and gold were first used for surgical implant and tooth root replacement devices (Jack, 1990). In the late 1960s, the materials of choice for the replacement of missing teeth had been oral implants (Reham and Michael, 2015). Oral implants or rather dental implants are materials that are used to repair, replace or enhance a patient's teeth. These materials include metals, ceramics, polymers, porcelains and composite resins (often made from plastics). Restorative dental materials make the reconstruction of the dental hard tissues possible. In many areas, the development of dental materials has progressed more rapidly than for other anatomical prostheses (Coleman e*t al.,* 2007). Physical and chemical properties of dental implant materials are well reported in literatures. Some of these properties include density, abrasion resistance, thermal conductivity, coefficient of thermal expansion, compressive strength, toughness, biocompatibility, creep and corrosion or degradation resistance. A promising implant material must have biocompatibility, sufficient strength, toughness, abrasion and degradation or corrosion resistance (Smith, 1993; Velmurugan, 2017). Pure metals were used predominantly due to their remarkable unique strength, fatigue strength, corrosion resistance and wear resistance in the early days of implant surgery. However, due to instability, the resulting problems related to poor biocompatibility, weak osseointegration, excessive rigidity and bone implant failure have prompted researchers to look for smart biomaterials to overcome these gaps (Xiaoqing *et al.,* 2017; Schwitalla and Müller, 2013). This further spurred the evolution of bio implant materials paving way for ceramic, polymer and composite implant materials. Although ceramics have lower toughness and polymers have lower strength, than metals, they are thermally insulating and tend to be more translucent. Hence, they offer protection from extreme of heat and cold and bear the potential of more lifelike aesthetics. Polypropylene (PP) is a kind of synthetic thermoplastic polymer, because of its light weight, good thermal resistance, low cost, ease of processing, full recyclability, good biological compatibility and chemical stability, it has been widely used in the field of tissue engineering (Du, 2004). Compared with metals (such as titanium), the elastic modulus of PP is similar to human cortical bone (Liang, 1999). Therefore, if PP reinforced with SBAP; faults related to low strength of PP would have been solved and consequently it could be a viable alternative material for dental implants

2. METHODOLOGY

2.1 Sugarcane Bagasse Ash Particulate (SBAP)

Sugarcane bagasse was collected from Kasuwar Mata Funtua. The bagasse was washed and dried under sun and then oven dried at 60°C. The bagasse was ashed at 700°C for 2 h 30 min. The ash was then milled and sieved to the prepared size of -250µm +250 µm and then stored in polythene bags to prevent it from moisture.

2.2 Sample preparation

In synthesizing the reinforced polypropylene composites, samples were manufactured with different additions of 10 - 50 per cent weight at constant intervals of 10% using compounding pressing machine. Compounding pressing machine has two rolling mills that move in anti-clockwise direction, the polypropylene was fed into the roller and the temperature is raised to 180°C, and then the filler was fed into the ball mill and mixed properly. This was done when all the additives have been measured as specified for each composition then compounded together to form the composite. Both bagasse ash particulate and polypropylene were compounded into homogeneous mixture in a two roll mill at a temperature of 160°C. Each composition after being compounded was pressed to aid the compatibility. The compounded mixture was placed in a mold of 120 x 12 x 3 mm and pressed with a pressure of $4MN/m^2$ until cured. The temperature of the plate was maintained at about 160°C during the pressing. At the end of press cycle, the board air cooled.

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2.4 Wear Test

The wear test was carried out using Anton Paar TRN ball-on-disc Tribometer (as per ASTM G99-95 standards), at constant speed of 15 rev/min along the sample surfaces under a constant load of 5N. Dry sliding condition was adopted in the test. Fifteen minutes used to observe the wear rate of the samples. The linear speed and dwell time were 10 cm/s and 506 seconds respectively. The volume of the samples wore and the subsequent wear rate determined.

2.5 Degradation Test

Fifteen (15) samples with dimension of 10 x 10 x 3 mm were taken from each composition of the composite (0-50 wt% SBAP). Initially, the samples weight were recorded. Five samples from each composition were taken and submerged into three different solutions namely, Hank's balanced salt solution (HBSS), artificial human saliva (AHS) and artificial human saliva with sodium fluoride (ASSF); at room temperature. After 5, 10, 15, 20 and 25 days, the submerged samples were removed and dried for 24 hours at ambient temperature. The samples then weighed again to get the final weight. The difference between the weight of samples before and after gave the weight loss of the samples (weight of sample degrades).

2.6 Biocompatibility Test

Four rats were used to carry out this test. Two of them were male and the other two were females. The rats were divided into two groups (A and B) each group consists one male and female. Male rats were weighted and mass of 36.2 g and 33.7 g obtained. Two female rats weighted 34.2 g and 37.9 g as well. The sample (20%SBAP) was converted into powder and then mixed with tween-80 solution to convert the fine powder into solution. Each group of rats was administered with different dosages. 0.1 mm^3 and 0.15 mm^3 dose of the liquid sample injected into the mouth of group A and group B respectively. Then the rats were placed under observation for 48 h to monitor any physical adverse reaction.

3. RESULTS AND DISCUSSION

Figure 1 demonstrates that optimum hardness obtained is at 50 wt% addition. Similarly, it is clear the hardness value increased considerably with filler loading. Perhaps, hard silica constituent in SBAP is likely to be the largest. Raul et al. (2002) designed a composite material for dental restoration. It was found that resin filled with hydroxyapatite indicated larger values of vickers hardness compared to unreinforced resin.

Figure 2 illustrated that wear resistance increased gradually with SBAP content. From the graph it is seen that 50wt% PP/SBAP composite exhibited the least wear rate compared to the other composites (Raju *et al.*, 2014). This is may be due to the higher packing fraction of the SBAP in the PP matrix. Also, alike trend was observed in formulating brake pad from Phenolic resin/periwinkles shell particles composites (Aku *et al.*, 2013).

The degradation of composite has been evaluated by per cent weight loss of different composites which were submerged in three different solutions i.e. AHS, ASSF and HBSS for 5 - 25 days (Figures 3-5). The per cent weight loss grows modestly with the immersion period across the composites in all the media. This is likely as a result of the penetration of solution into the composite causing hydrolysis of the composites' surfaces. Notwithstanding after 25 days of submersion, some composites demonstrate decline in degradation. This could be to the attribute of the formation of insoluble particles on the surface which renders the samples near inert (Montes & Draughn 1986). Due to high susceptibility to degradation, unfilled PP suffered deterioration the most. The result shows some kind of inverse relation between filler loading and weight loss. Nonetheless, in the AHS submersion events, it is not true for all the composition because at 50 wt% the weight loss is larger than that of 40 wt% which is probably due to the inhomogeneous dispersion of the particles. Again, composites immersed in HBSS degrade more progressively with PP/40 wt% SBAP having the least weight loss. Since HBSS is commonly used to wash cells and tissue in order to maintain them in a viable state (Joseph *et al.*, 2002; Souza, 2006), then, PP/SBAP composites would be compatible to human body. Accordingly, it is noted that weight loss is most in HBSS; this could be that there is more penetration in HBSS.

Biocompatibility Test Result

The mouth of the specimens (rats) was observed after 6 hours and there was no noticeable reaction in the rat's cavities. Subsequently, at the elapse of 24 h, the composite begins to blend and react with rats' cavity without noticing any side effect taking place as regards to affect the normal operation function of the rats. The last observation was conducted after 48 h and found out that; there is no adverse reaction such as necrosis (abscess formation) or inflammatory reaction in the neighbourhood of the implant. This clearly showed that the composite is biocompatible and non-toxic to the living tissues (Moser *et al.,* 1998).

4. CONCLUSION

The hardness of the composites increased by the incorporation of SBAP, likewise wear resistance improved in all the cases. Weight loss of the composite increased as degradation time increased in the three media. However, as degradation time further increased, the rate of degradation of some compositions decreased. The composites are physically biocompatible since no sign of toxicity was noticed when injected into the mouth of rats. Additionally, no significant deterioration was noted when submerged in HBSS. Since HBSS is commonly used to maintain cells and tissue in a viable state, then, PP/SBAP composites would be compatible to human body. Therefore, it could be recommended as dental implant material.

REFERENCES

Aku S.Y., Amaren S.G., Yawas D.S. (2013). Evaluation of the wear and thermal properties of asbestos free brake pad using periwinkles shell particles. Usak University Journal of Material Sciences 1: 99 – 108.

Du, L. C., Meng, Y. Z., Wang, S. J., & Tjong, S. C. (2004).

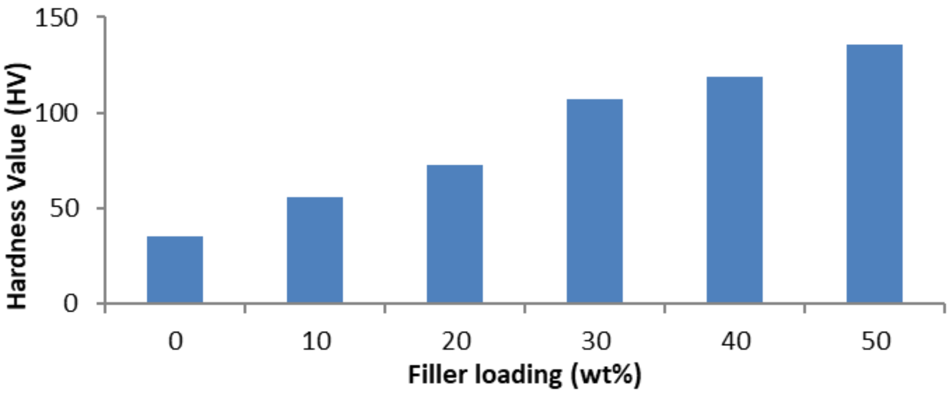

Figure 1: Variation of hardness value with the addition of SBAP

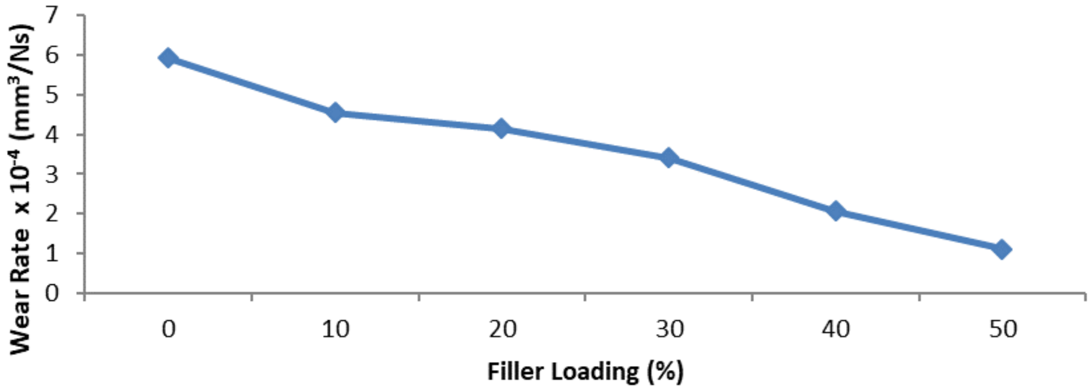

Figure 2: Effect of SBAP on wear behaviour of PP/SBAP composite

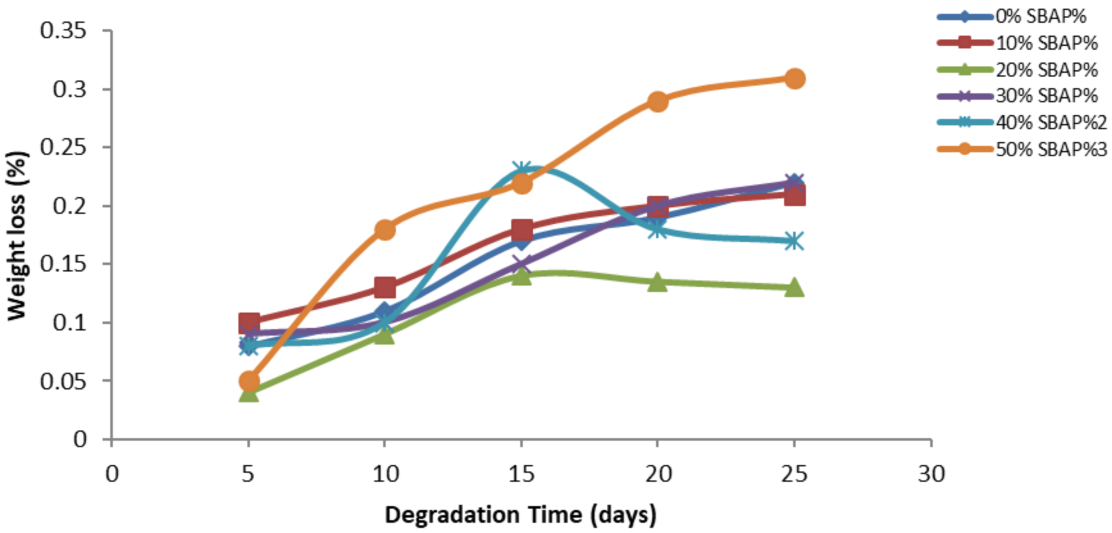

Figure 3: Weight loss of PP/SBAP composite as a function of degradation time in AHS solution

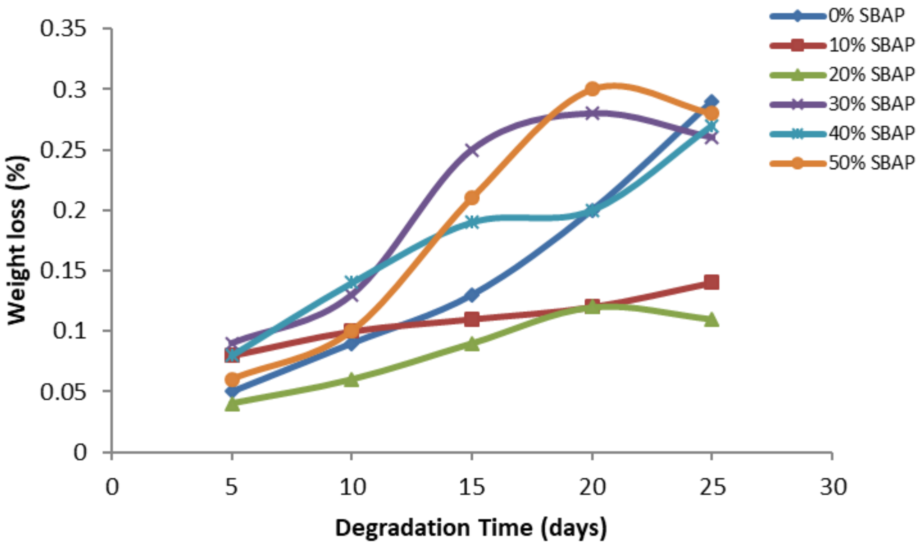

Figure 4: Per cent weight loss of PP/SBAP composite against degradation time in ASSF

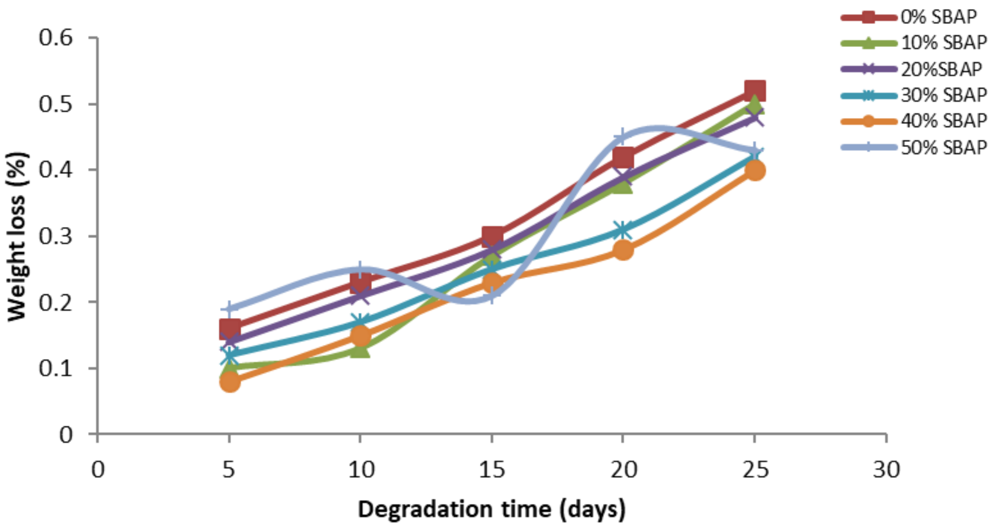

Figure 5: Weight loss of PP/SBAP composite as a function of degradation time in HBSS

Synthesis and degradation behavior of poly(propylene carbonate) derived from carbon dioxide and propylene oxide. *J. Appl. Polym. Sci , 92*: 1840–1846.

Coleman, M. J., Sissons, C. H., Anderson, S. A., Wong, L., & White, D. C. (2007). Microbiota of plaque microcosm biofilms: effect of three times daily sucrose pulses in different simulated oral environments. *Caries research*, *41* (5): 413-422.

Jack E. L. Dental Implant Biomaterials in: Research Report, Jada (1990) 121:716 – 719.

Joseph M.C, Valbert N.C., Pedro P. Manoel R. (2002). Hank's balanced salt solution: an alternative resuspension medium to label autologous leukocytes. Experience in inflammatory bowel disease, Brazilian archives of biology and technology, 45: 39-44 .

Liang, J. Z., Li, R. K., & Tjong, S. C. (1999). Tensile properties and morphology of PP/EPDM/glass bead ternary composites. *Polym. Compos* (20):413–422.

Montes-G, G. M., & Draughn, R. A. (1986). In vitro surface degradation of composites by water and thermal cycling. *Dental Materials*, *2*(5): 193-197.

Moser, V. C., Padilla, S., Hunter, D. L., Marshall, R. S., McDaniel, K. L., & Phillips, P. M. (1998). Age-and gender-related differences in the time course of behavioral and biochemical effects produced by oral chlorpyrifos in rats. *Toxicology and applied pharmacology*, *149*(1): 107-119.

Raju, K., Sudheer, M., Hemanth, K., & Bhat, T. (2014). Enhanced mechanical and wear performance of epoxy/glass composites with PTW/graphite hybrid fillers. *Procedia Materials Science*, *6*: 975-987.

Randolph, L. D., Palin, W. M., Leloup, G., & Leprince, J. G. (2016). Filler characteristics of modern dental resin composites and their influence on physico-mechanical properties. *Dental Materials*, *32*(12): 1586-1599.

Raul W.A., Anabel L.M., Manuel T.,Estrella O., Rafael R.C., Jaime M. **et al.** (2002). Mechanical properties of visible light-cured resins reinforced with hydroxyapatite for dental restoration, Dental Materials, 18: 49-57.

Reham B. O. and Michael V. S. (2015). A Critical Review of Dental Implant Materials with an Emphasis on Titanium *versus* Zirconia, *Materials* , *8*: 932-958;.doi:10.3390/ma8030932

Schwitalla A, Müller W D. (2013)"PEEK dental implants: a review of the literature". Journal of Oral Implantology, 39 (6):743-749.

Smith D. C. Dental implants: materials and design considerations. Int J. Prosthodont 1993; 6 (2): 106-17.

Souza B. D., Alves M. H., Santos L. G. P., Simões C. M. O., Felippe W. T., Felippe M. C. Fibroblast Viability after Storage at 20 °C in Milk, Hank's Balanced Salt Solution and Coconut Water, Brazilian Dental Journal (2016), 27 (4): 404-407. http://dx.doi.org/10.1590/0103-6440201600748

Velmurugan D, Santha A.M, Sarate S.G. (2017). Dental implant materials, implant design, and role of FEA - A brief review, J. Evolution Med. Dent. Sci. 6(44): 3487-3492, doi: 10.14260/Jemds/2017/753.

Xiaoqing S., Chenchen L., Tianjie C. and Hong L. (2017)The Study of PEEK Composites as the Dental Implant Materials, Journal of Simulation, 5(1): 5-7.