ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

Effect of Fiber Surface Treatments on Mechanical Properties of Sisal Fiber Polymer Composites–A Review

P.Srinivasa Kumar, Dr.C.Udaya Kiran, Dr.K.Prahlada Rao

Research Scholar, Department of Mechanical Engineering, J.N.T University, College of Engineering ,Anantapur, Andhra Pradesh, India

Professor, Department of Mechanical Engineering, J.B.Institute of Engineering and Technology, Hyderabad, India

Principal & Professor, Department of Mechanical Engineering, J.N.T.University,College of Engineering,Anantapur, Andhra Pradesh, India

ABSTRACT: This paper reviews the literature on the various aspects of sisal fibers and it's composites with a particular reference to chemical modifications. A major drawback of natural fibers is their polarity which makes it incompatible with hydrophobic matrix. This incompatibility leads to poor interfacial bonding between the fibers and the matrix. This in turn leads to impaired mechanical properties of the composites. This defect can be controlled by mercerization of fibers so as to make it less hydrophilic. The latest trends in surface modifications to improve interface adhesion for improvement in mechanical properties of sisal fibers are also discussed. This review also focuses on the influence of fiber content and fabrication methods, which can significantly affect the mechanical properties of sisal fiber-reinforced polymer composites. Recent research about chemical modifications of sisal fiber-reinforced composites, have also been presented.

KEYWORDS: Chemical modification, sisal fiber, mercerization, coupling agents interface adhesion and mechanical properties.

I. INTRODUCTION

The lignocellulosic, fibers, like sisal are inherently incompatible with hydrophobic thermoplastics, such as polyolefins. The major limitations of using these fibers as reinforcements in such matrices include poor interfacial adhesion between polar-hydrophilic fiber and non polar hydrophobic matrix, and difficulties in mixing due to poor wetting of the fiber with the matrix [1]. This in turn would lead to composites with weak interface .Properties of the composites are governed by the properties of the fiber, aspect ratio of the fiber, thermal stability of the fiber, fiber orientation and fiber-matrix interface[2]. Aspect ratio has a considerable effect on composite properties, hence it is important to conserve fiber length as much as possible during composite processing. Fiber aspect ratio must be in the range of 100-200 for optimum effectiveness. Fiber orientation has a significant effect on composite properties. During processing, the fibers tend to orient along the flow direction causing mechanical properties to vary in different directions. A poor interface is also a drawback in situations other than external mechanical loading. Because of differential thermal expansions of fiber and matrix, premature failure can occur at a weak interface when the composite is subjected to thermal stress. This problem can be overcome by treating these fibers with suitable chemicals. It has been reported that the use of alkalis and coupling agents such as silanes, titanates, zirconates, triazine compounds, etc. improve fiber-matrix adhesion and also the fiber-matrix interaction. Thus, adhesion between fiber and matrix is a major factor in determining the response of the interface and its integrity under stress. The present review here shows the utilization of sisal fibers with different surface treatments with the purpose of increasing the adhesion between the fibers and the matrix, and consequently to improve mechanical behavior of the composite material [1-2]. The treatment used is called mercerization [3] as per ASTM 1965. In other works, fiber treatment and fillers were reported to have improved fiber tensile strength and hardness as reported by Oladele et al.[4] and Ismail et al.[5], respectively. In this review, the effect of fiber modification and fiber loading on the mechanical properties, morphological and water absorption characteristics of sisal fiber/polymer composites are discussed.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

II. SURFACE MODIFICATION OF SISAL FIBERS

Belgacem and Gandini [6] classified the fiber treatments into three major types, namely physical treatments, physicochemical treatments and chemical grafting. From the author's study, it is revealed that the most promising approach of chemical modification seemed to be the one that gave rise to continuous covalent bonds between cellulose surface and matrix. Physicochemical treatments include corona, plasma, laser, vacuum-ultraviolet and γ-ray treatment with the aim to purify, oxidize or activate the surface of the lignocellulosic fibers The reinforcing ability of natural fibers is usually enhanced by fiber treatment, which leads to improvement in the properties of fiber- reinforced resulting polymer composites[7].

A. Alkali Treatment

Alkali treatment leads to the increase in the amount of amorphous cellulose at the expense of crystalline cellulose. The important modification occurring here is the removal of hydrogen bonding in the network structure.

B. Acetylation

Acetylation is a rather attractive method of modifying the surface of natural fibers and making it more hydrophobic.It has been shown to reduce swelling of wood in water and has been studied more than any other chemical reaction of lignocellulosic materials. The main principle of the method is to react the hydroxyl groups (OH) of the fiber with acetyl groups (CH_3CO), therefore rendering the fiber surface more hydrophobic. Acetylation has been shown to be beneficial in reducing moisture absorption of natural fibers. Reduction of about 50% of moisture uptake for acetylated jute fibers and of up to 65% for acetylated pine fibers has been reported in the literature **[**8].

C .Silane Treatment

Silane is a multifunctional molecule which is used as a coupling agent to modify fiber surfaces.The composition of silane forms a chemical link between the fiber surface and the matrix through a Sloane bridge. A solution of 1% phenyl triethoxy silane in acetone was prepared. Acetone was used in preference to water to promote hydrolysis to take place in presence of moisture on the surface of the fiber rather than with the carrier. The solution was maintained at pH 4 by adding acetic acid, stirred for 10mins. Portion of the dried alkali pretreated fibers were soaked in the solution for 1hour. Fibers were removed from the solution and dried in the hot air oven at 60^0C until they were dried.

D.Thermal treatment

The fibers are cleaned in order to remove dirt or impurities and the fiber is then placed in an oven and heated to an elevated temperature below the degradation temperature of the fiber for a period of time. Sreekumar et al. [9] heated the sisal fiber to a temperature of 100°C continuously for 2 h in an air circulating oven. While Huang et al. [10] heat-treated the sisal fiber at different temperatures (150, 200, 220 and 250 °C) and for different times (5, 10, 15, 20 and 30 min), to prepare sisal/polylactide composite. The best tensile strength of 74 MPa at 220°C for 10 min and flexural strength of 117 MPa when heat-treated at 150°C for 15 min were reported**.**

The irregularities of the fiber surface play an important role in the mechanical interlocking at the interface. The interfacial properties can be improved by giving appropriate modifications to the components, which gives rise to changes in physical and chemical interactions at the interface. An enormous amount of work has been conducted in the field of sisal fiber surface modification.Some of the recent studies have been presented in the literature study follows.

III. LITERATURE REVIEW

Kaewkuk etal.[11] investigated the mechanical properties of sisal fiber/polypropylene composite. They used sisal fiber obtained from Thailand and treated the fiber with 2% NaOH for 2 h and then dried it in an oven at 60°C over night. Three different fiber contents viz: 10, 20 and 30% sisal fiber with polypropylene were studied. The 30 wt% fiber

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

content showed the best property in terms of tensile strength and Young's modulus, with values of 26 MPa and 0.99 GPa, respectively.
Boopalan et al.[12] reported the results of comparative study of the tensile and flexural strengths of jute and sisal fiber treated with 20%NaOH. The treated sisal fiber shown a marginally better flexural strength of 82.3 MPa, which is ~2.75% more than jute fiber.

Rong et al. [13] experimented with unidirectional sisal-reinforced epoxy composites, which gave the best tensile strength .They treated the fiber with 2% NaOH alkali with a 58wt% fiber content and using compression moulding method to fabricate the composite. They had better result in terms of tensile modulus, flexural strength and flexural modulus of 5.55 GPa, 311.5 MPa and 23.75GPa, respectively.Khanam et al.[14] also reported , high mechanical properties; however this was not as high when compared with Rong etal.'s [13] data. The huge disparity in the results may be due to the fiber content, chemical treatment, mode of fabrication or the type of matrix used and an admixture of any of these.

Alvarez and Vazquez [15] studied the effect of acetylation and alkali-treatment on the properties of MaterBi-Y/sisal fiber composites. It was demonstrated that both treatments changed the morphology of the fibers by removing cellulosic and cementing materials, creating voids and producing fibrillation of fibers. These effects lead to a better adhesion between fibers and matrix. The authors suggested that the alkali treatment was more effective than acetylation.

Mwaikambo and Ansell [16] conducted the alkali treatment of sisal fibers and analyzed the changes with respect to the diameter and internal structure, such as cellulose content, crystallinity index, and micro-fibril angle. Alkalization treatment changed the internal structure of sisal fibers which exhibited approximately same specific stiffness as that of steel. Alkali treatment resulted in good increase in crystallanity nature of sisal fibers.Their results indicated that the structure of sisal fiber can be chemically modified to attain properties that will make the fiber useful as a replacement for synthetic fibers.

Rajesh et al. [17] prepared composites of 10% NaOH treated sisal fiber/PLA at different fiber contents (5, 10, 15, 20 and 25 wt %). It was reported that composites with 20 wt% treated fiber content showed better tensile strength and flexural strength of 30 and 17% higher than neat PLA, respectively, while the impact strength was 107% higher than the neat PLA. Increasing fiber content of treated fiber resulted in a decrease of the impact strength. The decrease in impact strength can be attributed to enhanced interfacial adhesion between the fiber and the polymer, instead of fiber pull-out, the composite fractured on receiving mechanical shock.

Syndenstricker etal.[18] reported the effects of varying NaOH concentration on sisal-polyester composite and observed that NaOH treatment of the sisal fiber decreases fiber density and 10% treatment concentration results in a rougher fiber surface.

Kanny and Mohan [19, 20] surface treated the sisal fiber with 40 g of NaOH–clay solution. The solution was prepared by adding clay to 40 g of NaOH and stirred vigorously until the clay dissolved completely in the solution. They immersed sisal fiber in the resulting solution for 1 h and then dried for 4 h at 60°C. They reported that the tensile strength, tensile modulus and strain of sisal/polypropylene composite increased by 14, 18 and 14%, respectively. NaOH–clay-treated fiber led to improvement in water uptake from 12.5 to 10.3% when compared with untreated fiber.

Mishra and Naik [21] treated sisal fiber with maleic anhydride (MA) in order to improve the mechanical properties. The treated sisal fiber/polystyrene composites also showed better impact strength of ~17 Nm/cm^2; similar result was obtained with the hardness (shore-D) test of ~78.

Luju He et al. [22] carried out surface modification of sisal fibers by alkali treatment, heat treatment and silane treatment respectively in order to enhance the interfacial adhesion of the fiber/polymer composite for mechanical properties improvement. Sisal fiber/polyethylene (PE) composites were fabricated at fiber contents of 10, 20, 30 weight% by using twin screw extrude equipment and their mechanical properties were studied. The test results of tensile and flexural show that mechanical properties increase after every treatment due to improved interfacial interactions. Silane treated fiber (with content of 30%) reinforced composites showed 18% increase in tensile strength and 32% in Young's modulus, while the alkali treated fiber (with content of 30%) reinforced composites performed 37% increase in flexural

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

strength. However, in case of impact strength, the treatment has been found to cause a reduction. It was also found with increasing fiber content, tensile strength, flexural strength and modulus of the PP composites increased but impact strength and elongation at break decreased.

Idowu David Ibrahim et al. [23] reported the results of their experimentation on impact of surface modification and nano particle on sisal fiber reinforced polypropylene nancomposite. Sisal fiber (SF) was treated with 5% NaOH for 2 hours at 70^0C. A mixed blend of sisal fiber and recycled polypropylene (rPP) was produced at four different fiber loadings: 10, 20, 30, and 40 wt%, while nanoclay was added at 1, 3, and 5wt %. Maleic anhydride grafted polypropylene (MAPP) was used as the compatibilizer for all composites prepared except the untreated sisal fibers. The characterization results showed that the fiber treatment, addition of MAPP, and nanoclay, enhanced the mechanical properties, thermal stability and reduced water absorption of the SF/rPP nanocomposites.The tensile strength, tensile modulus, and impact strength increased by 32.80, 37.62, and 5.48%, respectively, when compared to the untreated SF/rPP composites.Water absorption was reduced due to the treatment of fiber and the incorporation of MAPP and nanoclay.

C.Romao et al.[3] demonstrated the effect of different surface treatments i.e. mercerization with different volume percentage of Sodium Hydroxide (NaOH) and bath time immersion on mechanical properties of sisal/ epoxy composites as shown in Table.1. The results indicate that at high concentrations of NaOH and increased soaking times, the tensile strength decreases significantly ,which can be attributed to reduction in fiber diameter and the corresponding reduction in interfacing area, which results in ineffective adhesion .The change in Young’s modulus was not that much significant. The results are at good trend in comparison to the properties of neat epoxy resin.

Table 1. Comparison between the mechanical characterizations of the different fiber surface treatments

Composite	Tensile Strength MPa]	Modulus E [GPa]
1. Epoxy +25% sisal fiber without treatment	45.05	4.87
2. Epoxy +25% sisal fiber 4%(NaOH), 1 hour	49.85	6.51
3. Epoxy + +25% sisal fiber 4%(NaOH), 2 hour	62.81	6.64
4. Epoxy +25% sisal fiber 8%(NaOH), 1 hour	59.47	6.09
5. Epoxy +25% sisal fiber 8%(NaOH), 2 hour	49.51	6.17
6. Pure Epoxy Resin	49.98	2.91

Source Adapted from : C.Romao et al. [3].

Seenivasakumar. M and Karthick. **S** [24] investigated the mechanical behavior of sisal fiber and epoxy resin matrix composite at 30%, 35% and 45% fiber loading .Sisal fiber was treated in NaOH aqueous solution for 1 hour at room temperature. The maximum tensile strength of 30MPa was obtained for treated fiber at 45% fiber loading ,which is approximately 3 times higher than 9.25 MPa of the untreated fiber due to the surface modification which promoted good wettability and better fiber-matrix adhesion, allowing efficient stress transfer between the matrix and the fibers as shown in fig.1. The impact strength of composites increased by increase in the weight percentage of fiber. The impact strength of treated fiber is lower, compared to that of untreated fiber for same weight percentage as shown in fig. 2. The negative impact of the treated composites is attributed to the fact that the surface treatment improves the fiber-matrix adhesion, which leads to the fracture of fibers.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

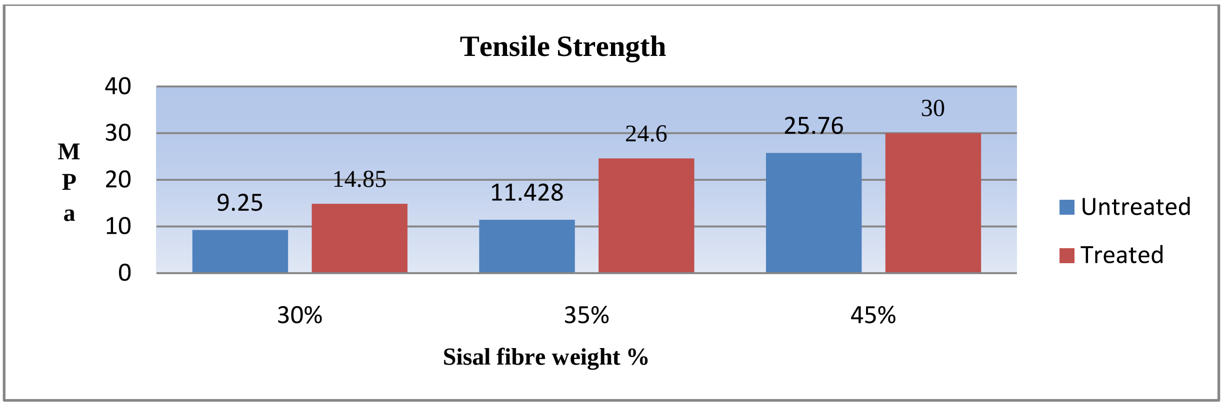

Fig .1. Tensile strength of untreated and treated sisal fiber

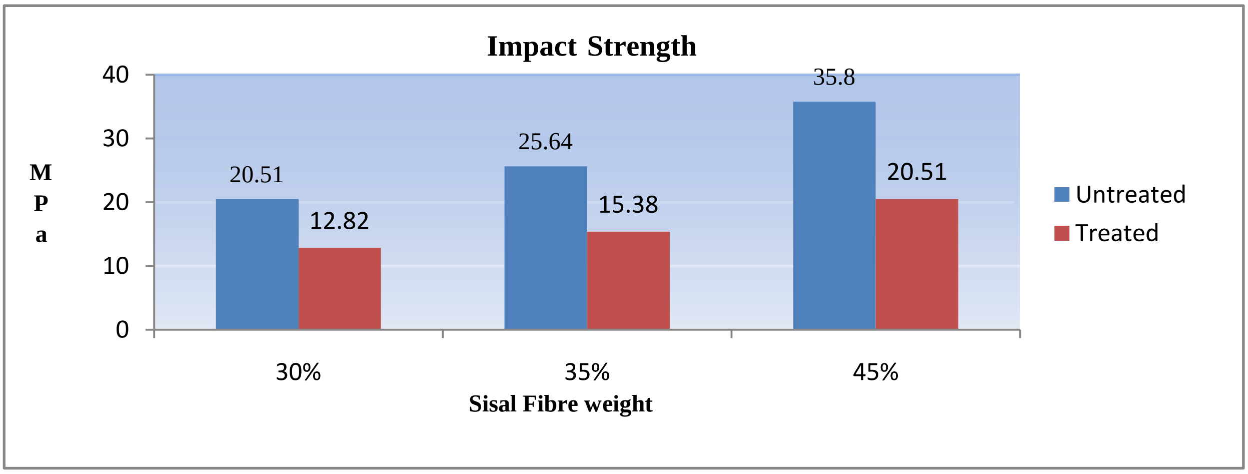

Fig 2. Impact strength of untreated and treated sisal fiber

IV CONCLUSIONS

The effects of fiber treatment on the properties of various sisal fiber composites have been reviewed in this paper. It is evident from the above studies that fiber treatment greatly improves the mechanical properties of sisal fibers by creating a rougher surface for good adhesion between the cellulosic fibers and the polymeric matrices. There should be a effective research thrust on exploring the modern surface modification techniques for improving the mechanical and water absorption properties of sisal fiber-reinforced polymer composites, even though alkali treatment proved to be efficient for all natural fibers. Research works indicate that other fiber surface treatment methods than NaOH treatment are also to be reviewed and addressed as well. It is interesting to note that there are many potential and economical silane coupling agents like lignin, shellac, chitin and chitosan [25]. It is also worth noting that biological coupling agents like fungus have also been found to increase fiber/matrix adhesion, which results in enhancement of mechanical properties.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 4, Issue 8 , August 2017

REFERENCES

1. Maya Jacob John., and Rajesh D. Anandjiwala., "Recent developments in chemical modification and characterization of natural fiber-reinforced composites", Polymer Composites, pp.187-207, February 2008.
2. Salisu,A.A.,Musa,H.,Yakasai,M.Y,.andAujara,K.M,."Effects of chemical surface treatment on mechanical properties of sisal fiber unsaturated polyester reinforced composites", Chem. Search Journal, Vol.6, Issue.2, pp. 8 -13, December, 2015.
3. C.Romão.,P.Vieira, J.L.,and Esteves., "Mechanical characterization of sisal fibers for reinforcing of composite materials with several different surface treatments", Dissertation of Master's degree in Mechanical Engineering, University of Porto, April, 2003.
4. Oladele, I.O., Omotoyinbo,J.A., and Adewara, J.O.T., " Investigating the effect of chemical treatment of the constituents and tensile properties of sisal fibre", J. Miner. Mater. Char. Eng, Vol.9, pp.569–582,2010.
5. Ismail. H., Edyham, M.R., and Wirjosentono. B., "Bamboo fibre filled natural rubber composites: the effects of filler loading and bonding agent", Polym. Test, Vol.21, pp.139144, 2002.
6. Belgacem, M.N., and Gandini, A ., " The surface modification of cellulose fibres for use as reinforcing elements in composite materials", Compos. Interfaces, Vol.12, pp.41–75, 2005.
7. Idowu David Ibrahim, et al.,"Mechanical properties of sisal fibre-reinforcedpolymer composites:a review",Composite Interfaces, Vol.23, Issue.No.1, pp. 15–36 , 2016.
8. Gassan, J., Mildner, I,. and Bledzki, A.K., " Influence of fiber structure modification on the mechanical properties of flax fiber-epoxy composites", Mech. Compos. Mater, Vol.35, pp.653–660,1999.
9. Sreekumar, P.A.,Saiah, R., andSaiter,J.M,et al. "Thermal behavior of chemically treated and untreated sisal fiber reinforced composites fabricated by resin transfer molding",Compos.Interfaces,Vol.15,pp.650,2008.
10. Huang,C.,Li.,X.Zhang,Y.,etal,"Properties of heat-treated sisal fiber/polylactidecomposites",J.Thermoplast. Compos. Mater, Vol. 28, pp.777–790,2015.
11. Kaewkuk, S., Sutapun ,W., and Jarukumjorn, K., " Effects of interfacial modification and fiber content on physical properties of sisal fiber/polypropylene composites"Composites Part B, Vol.45, pp.544–549,2013.
12. Boopalan M, Umapathy MJ and Jenyfer P, " A comparative study on the mechanical properties of jute and sisal fiber reinforced polymer composites", Silicon,Vol.4,pp.145–149,2012.
13. Rong MZ, Zhang MQ, and Liu Y, et al,"The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites," Compos. Sci.Technol,Vol.61 ,pp.1437-1447, 2001.
14. Khanam, P.N., Abdul Khalil, H.P.S., and Reddy G.R., et al. "Tensile, flexural and chemical résistance properties of sisal fibre reinforced polymer composites: effect of fibre surface treatment," J. Polym. Environ,Vol.19, pp.115–119,2011.
15. Alvarez ,V., and Vázquez. A.," Influence of fibre chemical modification procedure on the mechanical properties of Mater Bi-Y/sisal fibre composites",Composites Part A, Vol.37,pp.1672–1680,2006.
16. L.Y, Mwaikambo., and M.P. Ansell., J. Mater. Sci, Vol.41, pp.2497 , 2006.
17. Rajesh, G., Prasad, A.V.R., and Gupta, A.V.S.S.K.S., " Mechanical and degradation properties of successive alkali treated completely biodegradable sisal fiber reinforced poly lactic acid composites", J. Reinf. Plast. Compos,Vol. 3, pp.951–961, 2015.
18. T.H.D Sydenstricker et al., "Pull out and other evaluations in sisal reinforced polyester hybrid composite",Polymer Testing Vol 22, pp.375 - 380, 2003.
19. Kanny, K., and Mohan T.P., "Chemical treatment of sisal fiber using alkali and clay method", Composites Part A,Vol 43:1989–1998, 2012.
20. Kanny, K., and Mohan, T.P., "Surface treatment of sisal fiber composites for improved moisture and fatigue properties",Compos. Interfaces. Vol.20, pp.783–797, 2013.
21. Mishra,S., and Naik, J.B., "Effect of treatment of maleic anhydride on mechanical properties of natural fiber: polystyrene composites", Polym.-Plast. Technol. Eng, Vol.44, pp. 663–675, 2005.
22. Luju ,He., Li, Ma., and Xianyi, Shao., "Mechanical properties improvement of poly ethylene composite reinforced with sisa fibers treated by different methods", Proc.2nd International Forum on Electrical Engineering and Automation (IFEEA 2015), pp. 287-290,2015.
23. Idowu David Ibrahim., Tamba Jamiru . ,Emmanuel Rotimi Sadiku., Williams Kehinde Kupolati., and Stephen, Chinenyeze Agwuncha., "Impact of Surface Modification and nanoparticle on sisal fiber reinforced polypropylene nanocomposites", Journal of Nanotechnology, Article ID:4235975, pp.1-8, 2016.
24. Seenivasakumar, M., and Karthick ,S ., " Mechanical behavior of sisal fiber and epoxy resin matrix composite"International journal of pure and applied research in engineering and technology, Vol. 3, Issue .4 , pp. 325- 332, 2014.
25. B.L. Shah., L.M. Matuana, and P.A. Heiden, ''Novel coupling agents for PVC-Wood Flour composites,'' Proc. Annual Technical Conference-ANTEC Conference,Vol.10, pp.168 ,2005.