International Journal of Science and Technology Volume 3 No. 1, January, 2014

Mechanical Properties of Chicken Feather and Cow Hair Fibre Reinforced High Density Polyethylene Composites

[1,2]Oladele I. O., [1,2]Omotoyimbo J. A.,[1]Ayemidejor S. H.
[1]Department Metallurgical and Materials Engineering, Federal University of Technology, Akure, Nigeria
[2]African Materials Science and Engineering Network (AMSEN): A Carnegie-IAS (RISE) Network

ABSTRACT

This work was carried out to investigation the possibilities of utilizing animal fibres as reinforcement in polymeric materials. Fowl feather and cow tail hair were sourced from poultry and abattoir respectively. They were cut into 20 mm length followed by washing with water and sun drying. The fibres were used to reinforce high density polyethylene in predetermined proportions of 1,2,3,4 and 5 wt % in a random order. Flexural and tensile samples were produced from the compositions after which the respective tests were carried out. The results showed that fowl feather reinforced samples at 1-2 wt % gave a promising results in flexural properties while 3 wt % gave a promising result in tensile property. The upshot revealed that fowl feather can be used as reinforcement in high density polyethylene polymeric material in order to improve the mechanical properties of the polymeric material.

Keywords: mechanical properties, chicken feather, cow hair, high density polyethylene.

1. INTRODUCTION

Throughout history, technological innovations have helped humankind improve their standards of living through impressive rapid developments and research. However, some technology also creates negative environmental impact. Therefore efforts are invested in making use of natural based biodegradable and sustainable material that exist in nature rather than create a new material [1].

The Chicken Feather Fibre (CFF) is commonly described as a waste by-product and they are contributing to environmental pollution due to the disposal problems. There are two main chicken feather disposal methods that exist, a burning and burying. Both of them have negative impact on the environment. Recent studies on the chicken feather waste demonstrated that the waste can be a potential composite reinforcement. The composite reinforcement application of the CFF offers much more effective way to solve environmental concerns compared to the traditional disposal methods. Some of the advantages of the CFF are inexpensive, renewable, and abundantly available. The CFF as a composite reinforcement has certain desirable properties that includes; lightweight, high thermal insulation, excellent acoustic properties, non-abrasive behaviour and excellent hydrophobic properties. The CFF has the lowest density value compared to the all natural and synthetic fibres [2-5]. Martinez et al found that the CFF keratin biofibres allows an even distribution within and adherence to polymers due to their hydro-phobic nature and they reported that CFF reinforced composites have good thermal stability and low energy dissipation [6].

Chicken feathers are waste products of the poultry industry. Billions of kilograms of waste feathers are generated each year by poultry processing plants, creating a serious solid waste problem [7-8]. The Philippine poultry industry produced about 40 million broiler chickens annually [9]. These chickens generate about six million kilograms of waste feathers annually when the birds are processed in commercial dressing plants. Chicken feathers are approximately half feather fiber (barbs) and half quill (rachis) by weight, the quill being the stiff central core with hollow tube structure. Both feather fiber and quill are made of keratin (about 90% by weight), an insoluble and highly durable protein found in hair, hoofs, and horns of animals [10]. Keratin consists of a number of amino acids but largely made up of cystine, lysine, proline, and serine [11]. These amino acids tend to cross-link with one another by forming disulfide or hydrogen bonds resulting in fibers that are tough, strong, lightweight, and with good thermal and acoustic insulating properties [12]. The unique characteristics of keratin have generated interest in investigating the use of waste chicken feathers for a number of potential applications ranging from reinforcement in plastics to microchips [13-14].

In 1998, the US Department of Agriculture (USDA) developed the technology for separating chicken feathers into fiber and particulate (quill) fractions [15]. This discovery paved the way for the use of chicken fibers as reinforcements in composite products. Winandy et al. (2007) investigated the use of chicken feather fibers as a substitute for wood fibers in medium density fiberboard. The results showed that the fiberboards had a slight reduction in strength but improved dimensional stability and decay resistance compared with boards made from wood fiber. Other investigators used feather fibers to develop new bio-composites or as reinforcement in plastics [17]. A number of commercial applications have been explored to utilize fibers from chicken feathers. Unfortunately, due to the low volume requirements of these products they have not significantly reduced the volume of waste feathers generated each year. Composite building materials, such as fiberboard and particleboard, are high volume, high value applications which could potentially consume a large amount of waste chicken feathers. A simple, practical way to incorporate poultry feathers into composite boards is to bind them with Portland cement. Limited studies on this aspect of feather utilization have been reported [18]. However, if this could be proven feasible, it could offer an affordable new building material with both economic and environmental advantages. This paper reports on the use of waste chicken feather and cow hair fiber as reinforcement in High Density Polyethylene (HDPE) composites. This research was carried out to study comparatively the reinforcement efficiency of both fibres in the production of low cost and durable building materials suitable for tropical conditions.

2. MATERIALS AND METHODS

The materials that were used for this work were sourced from Nigeria. High Density polyethylene was obtained from Lagos State while cow hair and chicken feather were sourced from abattoir and poultry respectively in Ondo State.

Prior to the composite manufacturing, the Cow hair and Chicken feather were washed with water after wish they were sun dried for 1 week. The composites were fabricated with different fibre loadings (1%, 2%, 3%, 4% and 5%). The matrix material was weighed and poured into the flexural and tensile test moulds in wish the fibres were later spread. The composites were manufactured by using compression moulding machine maintained at 190 ^{O}C for 10 minutes at a pressure of 15 tons load. Tensile mould of gauge length 90 x 5 x 3 mm of a dumb-bell shape and flexural mould of 150 x 50 x 3 mm were used for the production of tensile and flexural samples respectively.

Mechanical Properties Tests

a. Determination of the tensile properties of the materials

In the present study, tensile tests were performed on INSTRON 1195 at a fixed Crosshead speed of 10 mm min^{-1}. Samples were prepared according to ASTM D412 (ASTMD412 1983) and tensile strength of the standard and conditioned samples were calculated.

b. Determination of the flexural property of the materials

Flexural test was carried out by using Testometric Universal Testing Machine in accordance with ASTM D790. To carry out the test, the grip for the test was fixed on the machine and the sample that has been cut into the test piece dimension of 150 mm x 50 mm x 3 mm, was hooked on the grip and the test commenced. As the specimen is stretched the computer generates the required data and graphs. The Flexural Test was performed at the speed of 100 mm/min.

3. RESULTS AND DISCUSSION

The variation of the flexural properties with the reinforcements was as shown in Figures1-4.

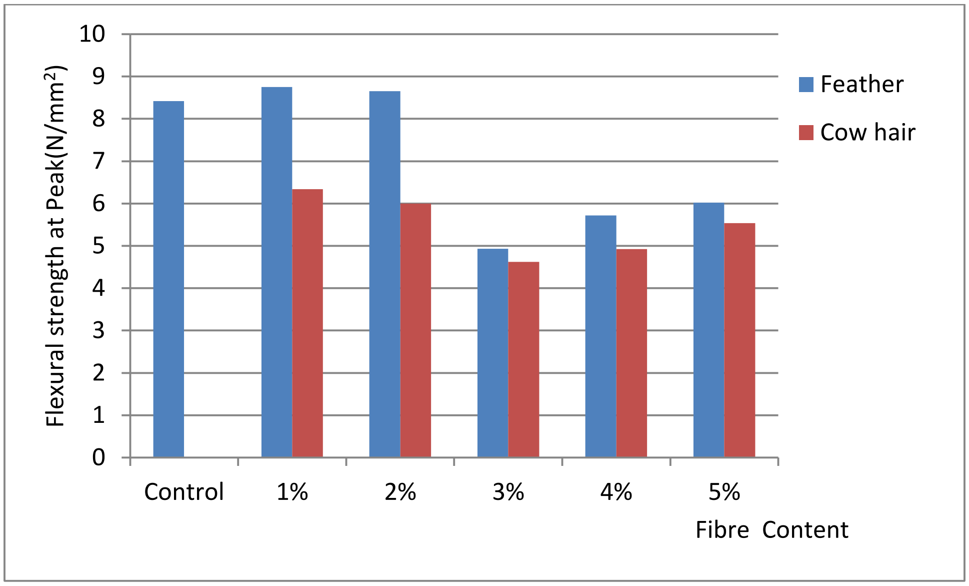

Figure 1: Variation of flexural strength at peak with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

Figure 1 show the effect of the fibres on the flexural strength at peak for the high density polyethylene (HDPE) composites from where it was observed that the strength decreases as the fibre content increases. However, the strength was mostly enhanced by chicken feather than cow hair. The result revealed that chicken feather gave better results for all the samples developed compared to cow hair reinforced samples. Addition of 1-2 wt % of the chicken feather gave the best results of 8.75 and 8.65 N/mm^2 compared to the control sample (unreinforced HDPE) with a value of 8.42 N/mm^2. Uzun et al (2011) used chicken feather and quail to reinforced polyester and vinyl ester and, it was found that the impact properties of the chicken feather fibre (CFF) reinforced composites are significantly better than the control sample however both the tensile and the flexural properties of the CFF reinforced composites have poorer values compared to the control sample. The result of the research showed that these properties decrease as the fibre content increases which was similar to what was obtained in this research except for the fact that lower fibre wt % reinforcements gave a better enhancement compared to the control sample.

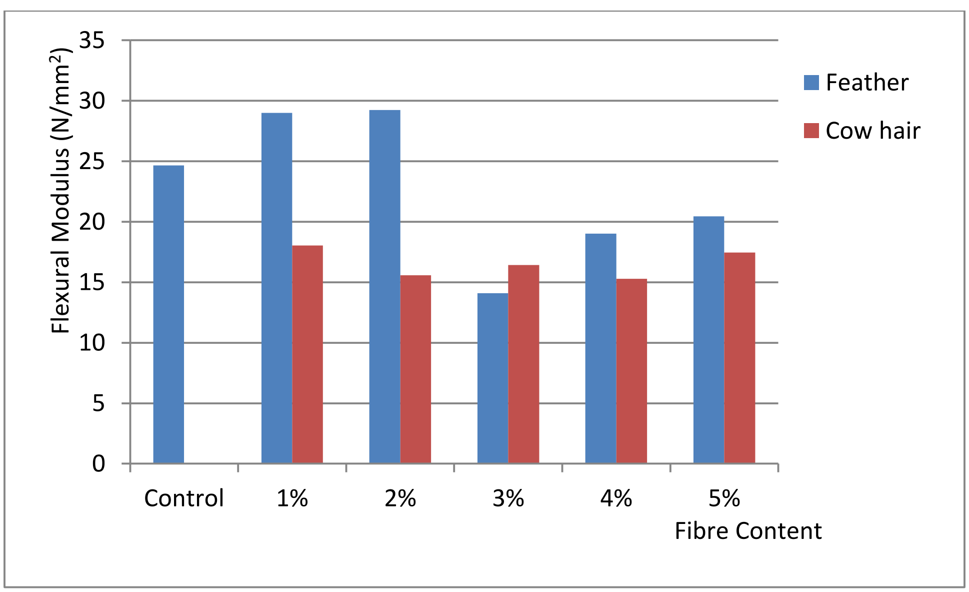

Figure 2: Variation of flexural modulus with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

The result of the variation of flexural modulus was as shown in Figure 2 where it was observed that 1-2 wt % chicken feather reinforcement gave the best results of 28.99 and 29.23 N/mm^2 respectively over and above the control sample which has a value of 24.67 N/mm^2.The result revealed a similar trend to what was obtained in Figure 1 except for the fact that cow hair gave better result at 3 wt % fibre reinforcement than chicken feather.

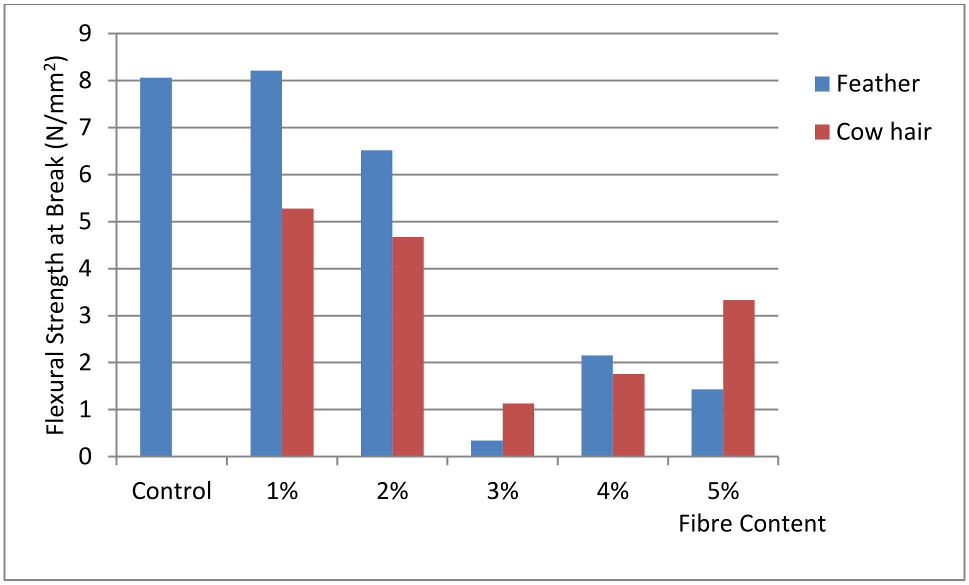

Figure 3: Variation of flexural strength at break with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

The result of the variation of flexural strength at break was as shown in Figure 3. From the result, it was observed that 1 wt % chicken feather fibre reinforced sample gave the best result of 8.21 N/mm^2 compared to control sample with a value of 8.06 N/mm^2.

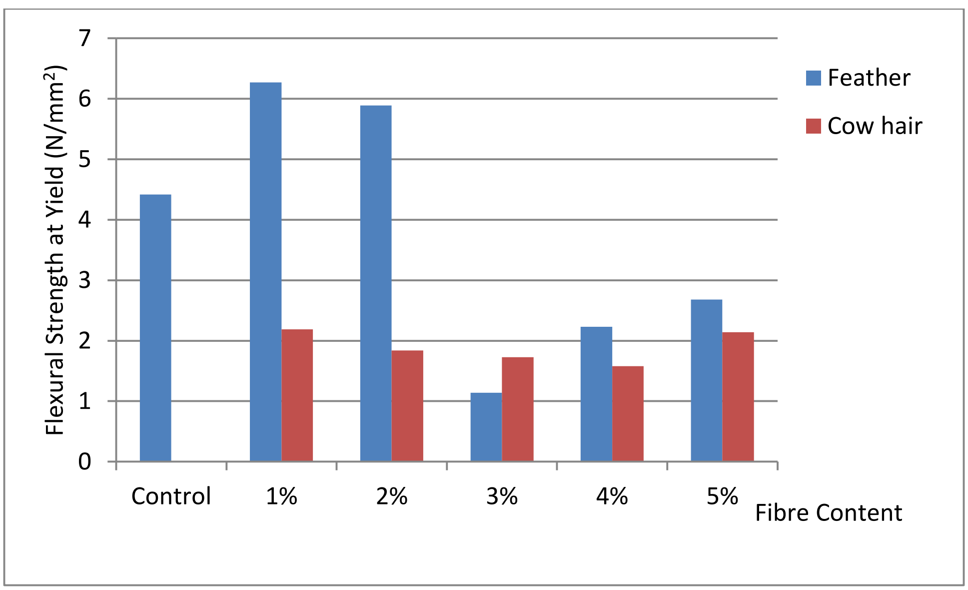

Figure 4: Variation of flexural strength at yield with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

Figure 4 show the result of the flexural strength at yield. The result follow similar trend with what was obtained in Figure 1. The values are 6.27 and 5.89 N/mm^2 for 1-2 wt % respectively compared to the control sample with a value of 4.42 N/mm^2. The flexural test results show that there is a decrease in these properties as the fibre content increases. This depreciation in values can be due to improper wetting of the fibres as it increases thereby leading to weak interfacial bonding between the chicken feathers and the HDPE and hence poor mechanical properties. However, at low fibre content, there is adequate wetting of the CFF by HDPE and hence, enhanced properties as shown in the Figures (1-4). Proper wetting is one of the major factors that determine the interfacial bonding strength in composites.

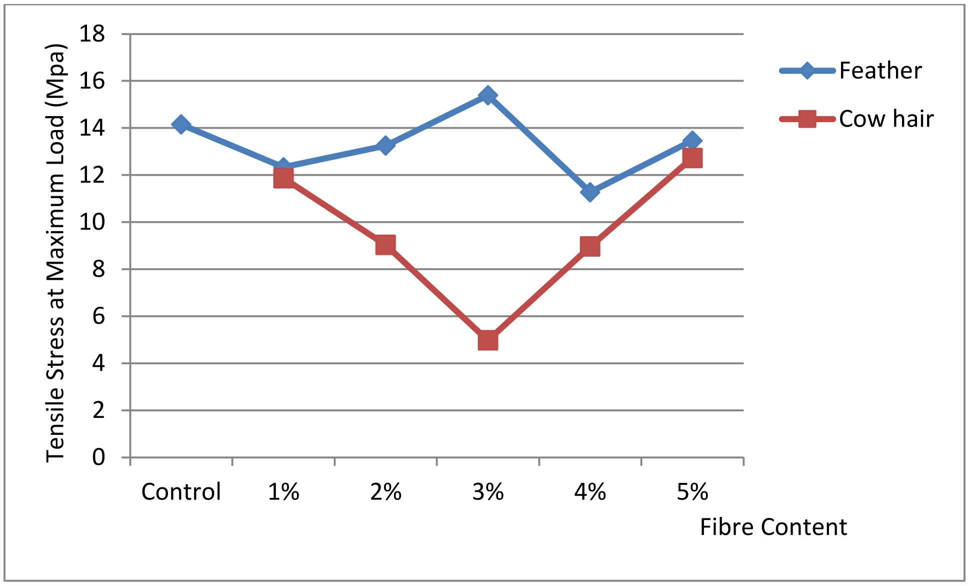

Figure 5: Variation of tensile stress at maximum load with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

Figure 5 show the result of the variation of tensile stress at maximum load for the cow hair and chicken feather fibres reinforced HDPE from where it was observed that the CFF reinforced samples gave better result than the cow hair. And the best result was obtained when 3 wt % reinforcement was used. The value was 15.39 MPa compared to the control sample with a value of 14.15 MPa. This sample was noticed to have least values in flexural properties but happened to be the best in tensile stress at maximum load.

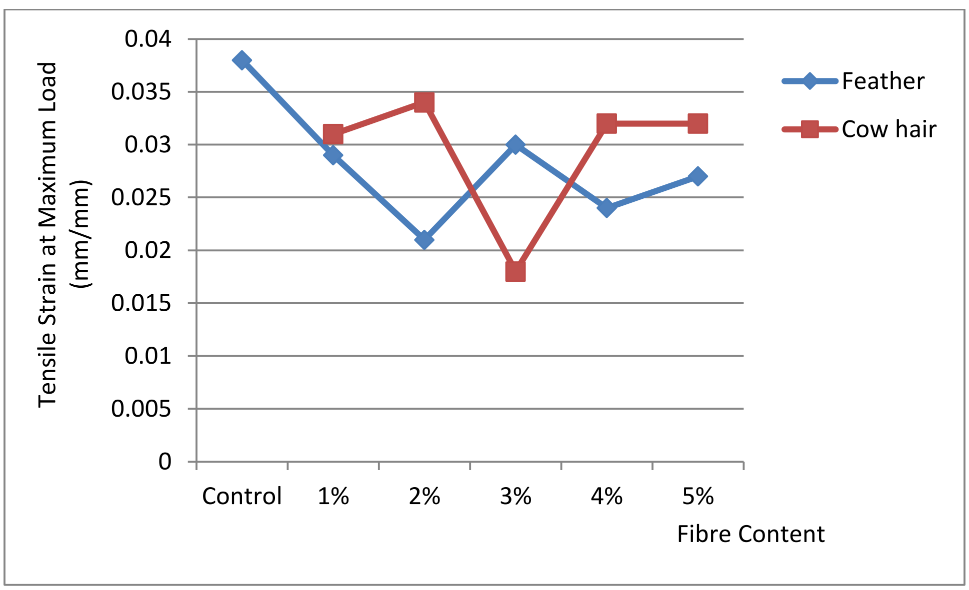

Figure 6: Variation of tensile strain at maximum load with fibre content for cow hair and chicken feather reinforced high density polyethylene composites.

The result of the tensile strain at maximum loading was as shown in Figure 6. From the result, it was shown that the unreinforced HDPE has the best tensile strain at maximum loading. The value was 0.038 mm/mm followed by sample reinforced with 2 wt % with a value of 0.034 mm/mm.

Considering the response of the materials to the mechanical properties, it was observed that, samples developed from 1-3 wt % gave the best results. This was due to adequate miscibility and wetting of the chicken feather fibre by the high density polyethylene at low fibre weight content.

4. CONCLUSION

The research was carried out in order to utilize both poultry and abattoir wastes that are being generated everyday across the globe for the production of materials for engineering applications. This was targeted for the purpose of developing materials with low-cost and superior properties that will not cause ecological and health problems. However, the result revealed that the chicken feather fibre (CFF) reinforced composites have potential applications due to its improved mechanical properties compared to the cow hair reinforced HDPE composites and the unreinforced HDPE. Chicken feather fibre reinforced composites gave better enhancement of the flexural and tensile properties due to proper wetting by the HDPE compared to the cow hair fibre. The outcome of the research revealed that low fibre weight content led to better enhancement of the mechanical properties as 1-3 wt % gave the best results.

REFERENCES

[1]. Hsie M., Tu C and Song P.S. (2008) Mechanical properties of polypropylene hybrid fiber-reinforced concrete, Material Science and Engineering A 494, 153-157.

[2]. Barone J.R., Schmidt W.F. and Liebner F.E. (2005) Compounding and molding of polyethylene composites reinforced with keratin feather fiber, Composites Science and Technology 65. 683-692.

[3]. Bullions T.A., Hoffman D., Gillespie R.A., O'Brien J.P. and Loos A.C. (2006) Contributions of feather fibres and various cellulose fibres to the mechanical properties of polypropylene matrix com-posites, Composite Science and Technology 66. 102 -114.

[4]. Huda S. and Yang Y. (2008) Composites from ground chicken quill and polypropylene, Composites Science and Technology 68. 790-798.

[5]. Reddy N. and Yang Y. (2007) Structure and properties of chicken feather barbs as natural protein fibres, Journal of Polymers and The Environment 15/2. 81-87.

[6]. Martinez-Hernandez A.L., Velasco-Santos C., de-Icaza M. and Castano V.M. (2007) Dynamical-mechanical and thermal analysis of polymeric composites reinforced with Keratin biofibers from chicken feathers, Composites B 38/3. 405-410.

[7]. Schmidt W.F. (1998) Innovative feather utilization strategies. Proc. National Poultry Waste Management Symposium, October 19-22, 1998. Auburn University Printing Services, pp. 276-282.

[8]. Parkinson G. (1998) Chementator: A higher use for lowly chicken feathers? Chem. Eng. 105, 21.

[9]. USDA Foreign Agricultural Service. (2005) Philippine Poultry and Products Annual 2005.Global Agriculture Information Network. Manila, October 2005. pp 10.

[10]. Schmidt W.F. (2002) Microcrystalline keratin: from feathers to composite products. In Wallenberger FT, Weston NE, Ford R, Wool RP, Chawla K. (Eds). Proc. Material Research Symposium. December 2-6, 2002. Boston, Massachusetts. pp. U1.5.1-U1.5.5.

[11]. Harrar B.S. and Woods E.F. (1963) Soluble Derivatives of Feather Keratin 1. Isolation, fractionation and amino acid composition. Biochemistry Journal 92: 8-18.

[12]. Poole A.J., Church J. S and Huson M.G. (2009) Environmentally sustainable fibers from regenerated protein. Biomacromolecules 10, 1-8.

[13]. Aluigi A., Vineis C., Ceria A and Tonin C. (2008) Composite biomaterials from fibre wastes: characterization of wool–cellulose acetate blends. Composites Part A 39, 126-132.

[14]. Huda H and Yang Y. (2008) Composites from ground chicken quill and polypropylene. Composites Science and Technology 68, 790–798.

[15]. Gassner III G, Schmidt W.F., Line M., Thomas C and Waters R. (1998) U.S. Patent 5,705,030.

[16]. Winandy J.E., Muehl J.H., Micales-Glaeser, J.A and Schmidt W.F.M. (2007) Chicken feather fiber as additives in MDF composites. Journal of Natural Fiber 4, 35-48.

[17]. Barone J.R. and Gregoire N.T. (2006) Characterization of fibre-polymer interactions and transcrystallity in short keratin fiber-polypropylene composites. Plastics, Rubber and Composites 35, 287-293.

[18]. Hamoush S.A and El-Hawary M.M. (1994) Feather fiber reinforced concrete. Concrete International 16, 33–35.

[19]. Uzun M., Sancak E., Patel I., Usta I., Akalın M. and Yuksek M. (2011) Mechanical behaviour of chicken quills and chicken feather fibres reinforced polymeric composites,Archives of Materials Science and Engineering 52/2. 82-86.