**FEB - FRESENIUS ENVIRONMENTAL BULLETIN**
Founded jointly by F. Korte and F. Coulston
Production by PSP - Vimy Str. 1e, 85354 Freising, Germany in cooperation with PRT-Parlar Research & Technology
Vimy Str 1e, 85354 Freising

**Printed in Germany-ISSN 1018-4619**

**Fresenius Environmental Bulletin is abstracted/indexed in:**
**Biology & Environmental Sciences, BIOSIS, CAB International, Cambridge Scientific abstracts, Chemical Abstracts, Current Awareness, Current Contents/Agriculture, CSA Civil Engineering Abstracts, CSA Mechanical & Transportation Engineering, IBIDS database, Information Ventures, NISC, Research Alert, Science Citation Index (SCI), Scisearch, Selected Water Resources Abstracts**

# CONTENTS

## ORIGINAL PAPERS

# POLYMER COMPOSITES REINFORCED WITH WASTE MARBLE DUST AND FIBERS FROM CHICKEN FEATHERS AS AN ALTERNATIVE MATERIAL

**Alev Akpinar Borazan*, Duygu Gokdai**

Bilecik Seyh Edebali University, Faculty of Engineering, Department of Chemical and Process Engineering, 11210, Bilecik, Turkey

## ABSTRACT

Feathers are a byproduct of poultry production. Marble waste powder is a solid waste material generated from the marble processing and which is presently mostly discarded in landfills. There is considerable interest in the protection of nature besides that the development of value-added products from these relatively inexpensive materials. This research proposed herein is directed at this goal and focuses on the manufacturing composite materials. Polyester based composite materials reinforced with waste marble dust and fibers recycled from waste chicken feathers were manufactured. Cobalt (1%) as accelerator, ButanoxAkzo M60 as hardener and poly pigment 27 dark brown as a source of pigment were used. Bending properties of composite materials were investigated to determine flexural strength, flexural modulus and hardness as well as some physical features such as density and water absorption. Determination of the chemical properties of chicken feathers was carried out according to AOAC standard. The values were high for manufacturing of the polymer composite with reinforced mixture ratio as 30:70 (wt %) of feather fiber/marble dust.

**KEYWORDS**
Polymer-matrix composites (PMCs), Natural fibers, Physical properties, Bending properties, Recycling

## INTRODUCTION

The composite manufacturing has been a wide area of research and has better mechanical properties because of its some superior properties such as low density, stiffness and light weight [1]. Thus, development of composite materials which are obtained from agricultural resources has recently attracted increasing interest. These composites are generally having lower density compared with inorganic fibers, environmentally friendly, and easy to obtain [2, 3]. Fibers obtained from the various parts of the plants are known as vegetable fibers. Animals can also provide a source of fibers. Chicken feathers are one of the valuable wastes to produce composite materials. The feather waste is usually disposed by either subjected for burning or landfill, which is considered as expensive process and not environmentally friend. Chicken feather fibers (CFFs) are kinds of animal-based nature fibers which are high strength, bio-degradable, commercially-available and low cost. The use of CFFs in composites as reinforcement offers an environmentally being solution for feather disposal and also benefits the poultry industry for cost reduction [4-6]. In most cases, the feathers are disposed of by burial, whereas an improved, more effective, and hopefully profitable utilization of the chicken feather waste is desirable [5]. Currently, the abundant quantity of poultry feathers produced annually by the poultry industry as a waste which can be effectively used as a reinforcing material [7, 8].

It is clear that the micro structural characterization fibers from chicken feathers have several individual properties like surface toughness, flexibility, high length to diameter ratio and hydrophobicity [9]. Many applications of chicken feathers have been discovered, but they have not significantly reduced the amount of waste feathers generated each year. Recently conducted several studies on this subject are available. Barone and Schmidt have prepared fibers of similar diameter but varying aspect ratio was mixed into low-density polyethylene (LDPE) by using a Brabender mixing head. They found from uniaxial tensile testing, an elastic modulus and yield stress increase of the composite over the virgin polymer was observed over a wide range of fiber loading [2]. Chicken feather fiber (CFF)/reinforced poly (lactic acid) (PLA) composites were processed using a twin-screw extruder and an injection molder by Cheng et al. Tensile moduli of CFF/PLA composites with different CFF content (2, 5, 8 and 10 wt%) were found to be higher than pure PLA, and a maximum value of 4.2 GPa was attained with 5 wt% of CFF [5]. Fibers of some critical length were manufactured by non-woven mat using spray bonding technique by Jagadeeshgouda et al. Tensile prop-erty of fiber, dimensional and strength of the quill was estimated. It was concluded that non-woven produced using CFF and composition with grass and paper are easy to handle during preparation of complicated components using hand layup technique [7]. Composite samples have been intentionally prepared with micro voids in order to produce light-weight composites with enhanced sound absorption capability by Huda and Yang. Mechanical and acoustical properties of composites were investigated and compared with jute–PP composites. Noise reduction coefficient (NRC) of ground quill composites was found 71% higher than that of jute composites [10]. Amieva et al. have prepared recycled polypropylene composites reinforced with quill from chicken feathers by extrusion process. Quill showed an excellent compatibility with the polypropylene matrix, revealed by the good dispersion [11]. Uzun et al. have produced reinforced composites were produced with vinylester and polyester resins with three fibre reinforcement loadings (2.5, 6, 10 wt %). It was shown that impact properties of the CFF reinforced composites are significantly better than the control composites [12]. Ghani et al. have prepared composite materials from poultry feather fiber. The effects of polyethylene grafted maleic anhydride (PEgMAH) on tensile properties; mor-phology, thermal degradation, and swelling behavior of low density polyethylene/CFF compo-sites were studied. It was found that the addition of PEgMAH offers better thermal stability in low density polyethylene (LDPE)/CFF/PEgMAH com-posites than LDPE/CFF composites [13].

Song et al. have prepared chicken feather protein (CFP)/nano-clay composite films and to evaluate the effects of various plasticizers and nanoclay concentrations on the mechanical prop-erties of the films. The result of study suggest that CFP composite films can be prepared with improved mechanical property by the addition of nano-clay and used as a food packaging material in the food industry [14]. One of widespread usage area for composites is the panels. For this purpose, a few study has been done [15]. Medium density fiberboard (MDF) panels were made by Winandy et al. with aspen fiber and 0-95% CFF in 2.5%, 5%, or 25% increments, using 5% phenol formaldehyde resin as the adhesive. Panels were tested for mechanical and physical properties as well as decay. They obtained that the addition of CFF decreased strength and stiffness of MDF-CFF composites compared with that of all-wood control panels [16]. Chicken feathers, a by-product of the poultry industry, were utilized as a film base material after extraction of chicken feather protein (CFP) by Song et. al. Composite films of CFP and gelatin were prepared, and their mechanical properties were investigated. The tensile strength and elongation at break of the CFP/gelatin composite film significantly increased as the gelatin content in the film increased [17].

Turkey has a significant amount of marble reserve is approximately 3872,000,000 $m^3$ [18]. Marble powder is produced from processing plants during the sawing and polishing of marble blocks and about 20 - 25% of the processed marble is turn into powder form. Every year million tons of marble waste form processing plants are released. The disposal of this waste marble on soils causes reduction in permeability and contaminates the over ground water when deposited along catchment area [19]. Using of waste marble dust plays an important role to prevent environmental problem and economic loss. It can be generally used as a reinforcement material in many areas and applications such as building materials, ceramics etc. Use of a Marble Waste Powder to production of polymer based composite materials is not very usual and there has been little research work done on the waste [20, 21]. In the study of Guru et al. various amount of fly ash, marble dust and polyester were used as base material, methyl ethyl ketone peroxide as hardener and cobalt naphtanats as accelerator were used to produce polyester matrix composite material. It was seen that hardness and the highest tree point bending strength were obtained at polyester/filler (marble dust +fly ash) ratio of 0.38. The optimum values for three point bending strength and hardness test were found as 32.78 $N/mm^2$ and 99 Shore A, respectively [22].

CFF/PLA composites were prepared by using extrusion and injection molding process by Baba and Ozmen. Mechanical properties of composites such as compressive strength, flexural modulus and hardness were investigated. The PLA reinforced CFF composites exhibits higher Young's modulus, compressive strength, flexural modulus and hardness but had lower tensile strength, elongation at break, bending strength and impact strength than PLA [23]. Billions of kilograms of waste feathers are generated each year by commercial poultry processing plants creating a serious solid waste problem in many countries. Several commercial applications have been explored to utilize fibers from chicken feathers. However, due to the low volume requirements of these products they had not significantly reduced the volume of feathers generated each year [24]. The objective of this research is to find alternative and high value uses for feather materials.

The experimental research was investigated application with high potential: feather fiber as raw material for manufacturing composites. The specific objectives are: 1. to determine optimum filling ratio of the chicken feather fiber and marble dust into polymer composite materials 2. to evalu-ate bending, dimensional and physical properties after the manufacturing of polymer composite rein-forced with waste of poultry feathers fiber and marble dust.

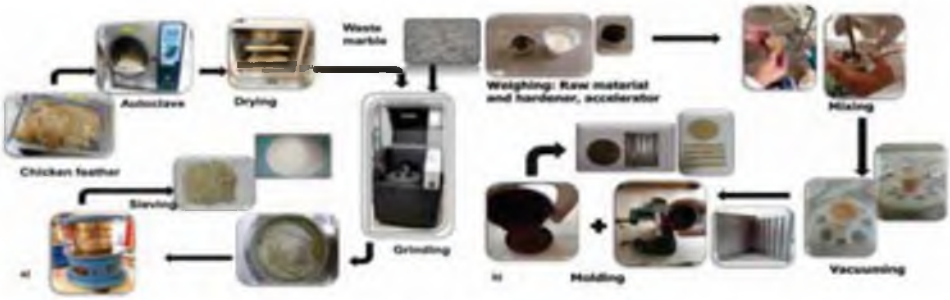


**FIGURE 1**
**Graphical diagram of process a) Pretreatment b) Composite preparation**

**TABLE 1**
**Composition of polyester composites containing waste marble powder dust and chicken feather**

| Composite Code | Ratios of filling blends- (Marble powder: Chicken feather) | Marble powder (*wt %) | Chicken feather (*wt %) | Polyester (*wt %) |
|---|---|---|---|---|
| **CFF0** | 100:0 | 40.0 | 0 | 60.0 |
| **CFF10** | 90:10 | 36.0 | 4.0 | 60.0 |
| **CFF20** | 80:20 | 32.0 | 8.0 | 60.0 |
| **CFF30** | 70:30 | 28.0 | 12.0 | 60.0 |

*Weight Percent [wt%]

## MATERIALS AND METHODS

**Materials.** Polyester (383-G) was used as a matrix material. Waste marble powder and waste chicken feather used as reinforcing materials at different ratios, was obtained from the poultry and the marble factories in Bilecik, Turkey. Methyl ethyl ketone peroxide (Butanox M60) used as a curing agent was purchased from Akzo Nobel. Resin and hardener were mixed in a ratio of 60:1.8 by weight as recommended. Cobalt (1%, w/w) as accelerator, poly pigment 27 dark brown as a source of pigment and polyester were supplied by Poliya Composite Resins and Polymers Inc., Turkey. Resin and accelerator were mixed in a ratio of 60:0.75 by weight as recommended within limitation.

**Filler preparation.** A pre-treatment was required to stabilize and transform waste chicken feathers into a stable technical material (Figure 1a). First of all, chicken feathers were washed with tap water, then applied autoclave process (135°C, 20min.) and dried in oven 60°C, 24 hours to be clean, sanitized and odor free. Afterward, quills were separated from barbs and retain parts cut into small pieces.

Finally, last drying was at 105°C, 2 hours in oven. Chicken feather moisture was decreased to approx. 10%. Dried and chopped feathers and also marble pieces then ground into powder form using a laboratory Mill Pulverisette 9, (Fritsch, Ger-many). The grinded particles sieved under 0.425 µm. The waste marble powder which was produced from the marble processing plants during the cutting, shaping and polishing, was ground and collected on 90 µm ring sieve so it was turn into the dust form. Then, dust was oven dried to moisture content of 0-1% in lab oven at 100°C and stored in a sealed container.

**Composite manufacturing process.** The polyester matrix was compounded with reinforce-ment fillings in a ratio of 40:60 by weight. The reinforcement fillings were mixed in different ratios by weight. The waste material formulations, which are given per the mass proportion in percentage, used for the composites are presented in Table 1. The workability of polymer composite mixture de-creased significantly as the proportion by weight of CFFs increased over 12.0%.

Composite preparation process was shown in Figure 1b. The reinforcement material and poly-ester resin was first mixed mechanical stirrer (Stuart scientific stirrer SS3, UK) within the indicated ratios. After then, performed using a speed of 500, 1000 and 1500 r/min, 5 minutes cycle time for each. Mixture was hold on under the vacuum in 5 min. Then accelerator and hardener were added to mixture and the last mixture was poured into a mold. Curing condition for com-posites were 105°C, 1 hour in an oven (Binder, Germany).

**Chemical, physical and bending testing.** The percentage of the components of feather varies from species to species. That's why compositional information was reported in chemical analyses of feather samples. It was determined by standard methods [25]. Moisture was assayed by oven-drying at 105°C until constant weight. Crude pro-tein was estimated as Kjeldahl-nitrogen using factor 6.25. Crude lipid was determined by soxhlet extraction with petroleum ether for 6 h. Ash content was analyzed by incinerating samples at 550 °C for 12 h in a muffle furnace.

Physical and mechanical tests were carried out on each of the composites to determine relevant properties. Three to five samples were used per composite for each property evaluation test. The physical properties examined were density, thick-ness swelling (TS) and water absorption (WA). These tests were carried with test sample sizes of 5x5 cm. The density was measured using a gas pycnometer, Micromeritics the AccuPyc II 1340 model. Water absorption was determined from the measured weight gain or loss of the composite samples during the 24 hours immersion period. Thickness swelling was determined from the average of the measured change in thickness at four locations on each sample after immersion in water for 24 hours [15].

Flexural tests were conducted using the three point bending set-up according to EN ISO 178 TS 985. The samples with dimensions of 100 mm × 10 mm × 4 mm (length x width x thickness) were tested using Shimadzu AG-IC testing machine. Three point bending tests were carried out at a bending speed of 2 mm/min and the maximum fracture loads of the three-point bending test were obtained. At least five specimens were tested for each processing condition. The bending measure-ments were also performed at the ambient condi-tions of 23±2°C. Flexural strength and flexural modulus were then obtained using the expressions:

$$\sigma_f = (3PL)/(2bd^2) \quad (1)$$

$$E_f = (L^3m)/(4bd^3) \quad (2)$$

where L is the support span; b, the width of the specimen; d, the thickness; P, the maximum load; and m, the slope of the initial straight line portion of the load–displacement curve.

Hardness test is a simple one and gives good info on the microstructure relationships of polymer composites. Shore hardness is a measure of the resistance of a composite sample. 8 cm in diameter to penetration of a spring loaded needle-like in-denter. Five replicates of each composite formu-lation were tested to determined averaged hardness. The test of Izod impact was performed by Izod impact instrument (DVT CD, Devotrans Quality Control Test Instruments Ltd., Turkey). The impact tester with a 6.0 J pendulum hammer was employed to determine the impact strength by the hammer falling angle is 150°, falling velocity is 3.8 m/sec. For each composition, three bars were test. The impact strength ($\sigma i$) was calculated using the following equation:

$$\sigma i = E/A \quad (3)$$

where E is the impact energy required to break a sample with a ligament of area A.

The fracture surfaces of the flexural test specimens were characterized with high resolution field emission scanning electron microscopy (SEM, Zeiss Supra 40VP, Germany). The samples were coated with platinum before examined. The image analysis of composite samples and SEM study were prepared from the edges of the three point bending test specimens.

**Statistical analysis.** An analysis of variance was conducted to evaluate the effect of the rein-forced chicken feather fiber and waste marble dust content on the dimensional stability and mechanical properties of the composites. Quantitative data were expressed as means ± Standard Error. Statistical differences were estimated by one-way ANOVA followed by Tukey's multiple range test, and a probability level of 0.05 was used to indicate sig-nificance. All statistics were performed using stat graphics Centrion XV. The same letters beside the vertical axis and in the same column (Figure 3, Table 3 and 4) indicate the values are not significantly different ($p > 0.05$).

**TABLE 2**
**Proximate composition of chicken feathers as dry basis**

| | (%) |
|---|---|
| **Crude protein** | 77.00±0.78 |
| **Crude fat** | 3.95±0.41 |
| **Ash** | 1.85±0.11 |
| **Moisture** | 10.94±0.18 |

## RESULTS AND DISCUSSION

The proximate composition of chicken feathers is listed in Table 2.

The chicken feathers presented high protein content. Acda (2010) reported higher protein values for feathers and Tseng et al. (2011) found similar values for composition of the chicken feathers. Both feather fiber and quill are made of keratin, an insoluble and highly durable protein found in hair, hoofs, and horns of animals. Keratin consists of a number of amino acids, 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 [24, 26, 27].

**TABLE 3**
**Density and the dimensional stability properties of composite samples**

| Composite codes** | Density, ($g/cm^3$) | TS, 24 hours (%) | WA, 24 hours (*wt %) |
|---|---|---|---|
| **Polyester** | 1.1892±0.0004 | 0.68±0.01$^{e}$ | 0.18±0.01$^{a}$ |
| **CFF0** | 1.7741±0.0010 | -0.48±0.02$^{a}$ | 2.44±0.10$^{d}$ |
| **CFF10** | 1.7421±0.0008 | -0.14±0.02$^{b}$ | 0.29±0.02$^{b}$ |
| **CFF20** | 1.6680±0.0005 | 0.30±0.01$^{d}$ | 0.35±0.03$^{b}$ |
| **CFF30** | 1.6330±0.0004 | 0.07±0.00$^{c}$ | 0.55±0.02$^{c}$ |

*Weight Percent [wt%]
Values are presented as mean ± Standard Error (n=3); values with different superscripts in the same row differ significantly (P<0.05)
** See Table 1 for composite formulation.

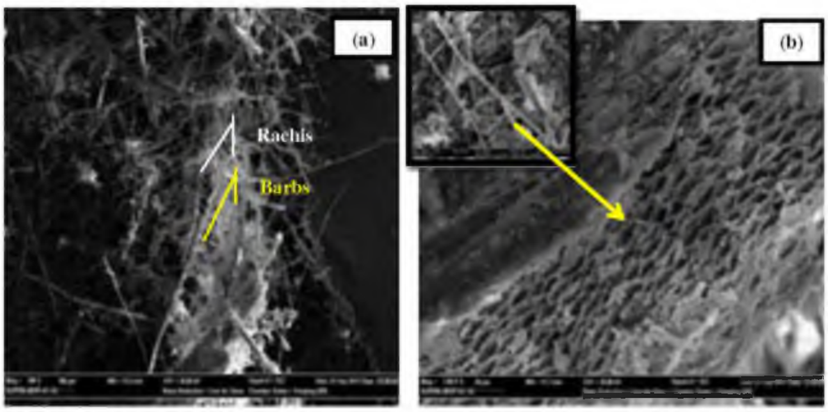


**FIGURE 2**
**Microstructures of the chicken feathers (a) and zoom into barb images (b)**

The physical properties of polymer composite samples were statistically different in each other ($p < 0.05$) (Table 3). The results for the density, TS and WA of the composite samples are presented in Table 3. The densities of the composites with the four different filler ratios are higher than the density of the matrix polyester. Only minimal differences were evident amongst the four composites and the control sample composite. When chicken fiber loadings increased with reduction in the quantity of marble dust, the density of composite decreased as an expected [12]. The present study is not shown corroboration with Amieva et al. (2015) who observed a significant effect of quill concentration onto density properties. All density values of R-PP (recycled polypropylene)/Q (quill from chicken feathers) composites decrease compared with R-PP density. However, when quill content increase in composite density increased.

As the samples were immersed in water for 24 hours the moisture absorption increased along with swelling by decreasing the water resistance strength [28].

Thickness swelling improved when increasing the chicken feather ratio was to 30%. Addition of the excessive chicken feather also reduced compos-ite strength properties by increasing the porosity of the polymer composites [24]. The thickness swell-ing results for the composites were also very different to that for Polyester, with values ranging from -0.48 to 0.30%. TS values of CFF0 and CFF10 composites are negatively. Two reasons should be effective on the results; first, marbles are calcareous metamorphic rocks. Their main com-ponent is calcite, a mineral formed of calcium carbonate $CaCO_3$, require an acidic pH (less than 7) in order to dissolve at a useful rate. Actually, marble chips are slightly soluble at a very slow rate, in water [29]. Second, neither chemical treatment on the chicken feather nor coupling agent was to be used while the manufacturing process. Unfortu-nately, strongly chemical bond did not provide between two dissimilar materials, feather fiber (organic) and marble powder (inorganic) [30,31]. CFF30 had the lowest swelling of 0.069%. The water absorption of the composites was 0.29±0.02-2.44±0.10 wt% compared with 0.18±0.01wt% for the unfilled matrix material (Polyester). Amongst the composites, CFF10 had the lowest water absorption of 0.29±0.02wt%, which had approxi-mately minimum ratio feather and barb quantities. A feather barb is the lateral fiber branching (in parallel rows) on the shaft. The rachis and barbs are soft and pliant and readily absorb water.

Water molecules can diffuse into the material and become trapped there, especially if the material contains voids that can hydrogen-bond the water in place (Figure 2).

The mechanical properties test results are summarized in Table 4. Mechanical property tests indicated real differences in the materials. The use of waste marble powder or mixing chicken feather fibers with different ratios used in this study seemed to have significant effect ($p < 0.05$) on me-chanical properties. The additional chicken feather fiber to polyester composite had very little negative effect on internal bond [12, 32, 33].

The flexural strength of the composites was 48.65-63.84 MPa, and was substantially lower than the values obtained for and 69.58 MPa. The values for the composites made without feathers, CFF0 had the lowest flexural strength (48.65MPa) but the highest flexural modulus (8.44GPa) while the CFF30 had the highest flexural strength with maximum ratio feathers material having the lowest modulus of elasticity. The addition of chicken feather fibers yield better results with improvement in flexural strength of 63.84±1.15 MPa compared to CFF0 [12, 24]. The elastic modulus results of control composite, Polyester and different fiber loaded composites were demonstrated and com-pared in Table 4. The flexural modulus of fiber loaded composites decreased with increasing CFFs content. Although of this, the flexural moduli of CFFs composites were significantly higher than the control composite, PMC which was 3.57±0.05GPa. Acda (2010) reported that modulus of elasticity and flexural strength of the feather-cement boards decreased as the proportion of feathers was increased. This observation is similar with elastic moduli of CFFs composites. It might be no sufficient interaction progress between CFFs and waste marble powder and polymer matrix [32, 34]. Hardness test was used in order to evaluate some physical characteristics of the materials. As a result of Shore D hardness of polyester composite samples ranged from 81.25±0.5 to 85.25±1.26. According to hardness test, increasing of chicken feathers ratio into manufacture was caused to be decreasing to the hardness of composites. The izod impact property is another key importance characteristic of the composite structure, especially due to its significance in many applications. Impact strength for the composites without and with dif-ferent ratios of CFFs is presented in Figure 3.

The impact values of composites decreases with the fiber loadings. The results indicate that impact strength could not be enhanced with CFFs. The differences were obvious with CFF0 polyester composite. On the other hand, impact test also shows that the energy absorbed by all the composites. Figure 3 shows a linear decrease in energy with increasing fiber content [35].

Flexural modulus decreases with the content of increasing chicken feathers and decreasing the ceramic phase. Hardness results show similar values for each of composite samples. Strength values increase with the content of increasing chicken feathers and decreasing the ceramic phase. This is because, as seen from the SEM-SE images there are a strong matrix-reinforcement interface interaction.

The SEM was operated to determine microstructure, and fiber orientation characteristics of the polished surfaces of polyester composite specimens. Micrographs of the composite samples were obtained using a Zeiss Supra 40VP, scanning electron microscope (Germany) were shown in Figure 4a to 4e. Prior to SEM observation, the samples were fixed and then coated with platinum.

All samples were examined using an accelerating voltage of 5 kV. The SEM images show that the increasing feather fibers were not well dispersed each other and also in polyester matrix, which was important to obtain physical and mechanical properties [5]. It can be observed in Figure 4b to 4e voids were decreased with the increase chicken feather fibers. The use of waste marble powder and CFFs together were expected to bring the quality of the fillers–matrix interface in between the polymer composites. Figure 4 was indicated that whether or not this actually can happen.

**TABLE 4**
**Test results of composite samples force and bending properties**

| Composite code** | Max. Force (N) | Flexural strength (MPa) | Flexural modulus (GPa) | Shore D |
|---|---|---|---|---|
| **Polyester** | 146.88±13.37 | 69.58±0.65$^{e}$ | 3.57±0.05$^{a}$ | 81.25±0.5$^{a}$ |
| **CFF0** | 107.50±3.92 | 48.65±0.58$^{a}$ | 8.44±0.11$^{e}$ | 84.25±0.96$^{b}$ |
| **CFF10** | 116.88±3.84 | 54.07±0.61$^{c}$ | 7.83±0.12$^{d}$ | 85.25±1.26$^{b}$ |
| **CFF20** | 112.5±4.53 | 51.06±0.55$^{b}$ | 7.47±0.10$^{c}$ | 84.5±2.65$^{b}$ |
| **CFF30** | 137.5±7.22 | 63.84±1.15$^{d}$ | 6.55±0.16$^{b}$ | 83.25±2.36$^{ab}$ |

Groups with same letters in column indicate that there is no statistical difference ($p < 0.05$) between the specimens according Turkey's multiply range test.
Values are presented as mean ± Standard Error (n=5).
** See Table 1 for composite formulation

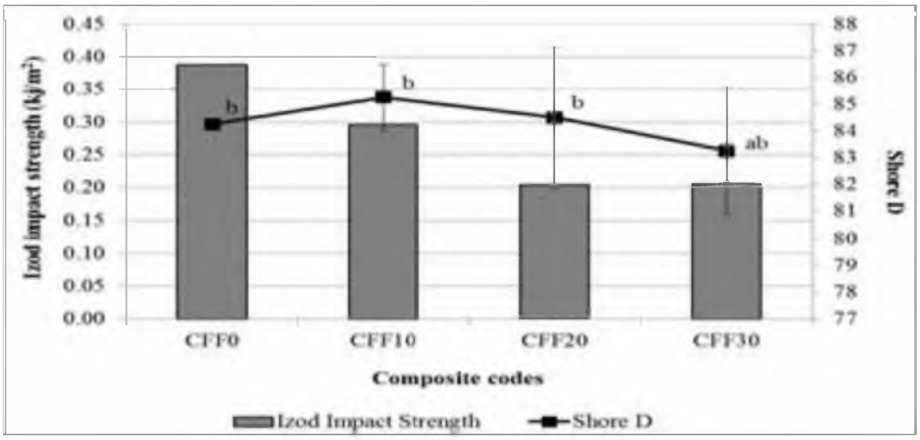


**FIGURE 3**
**Izod impact and hardness results of composites**

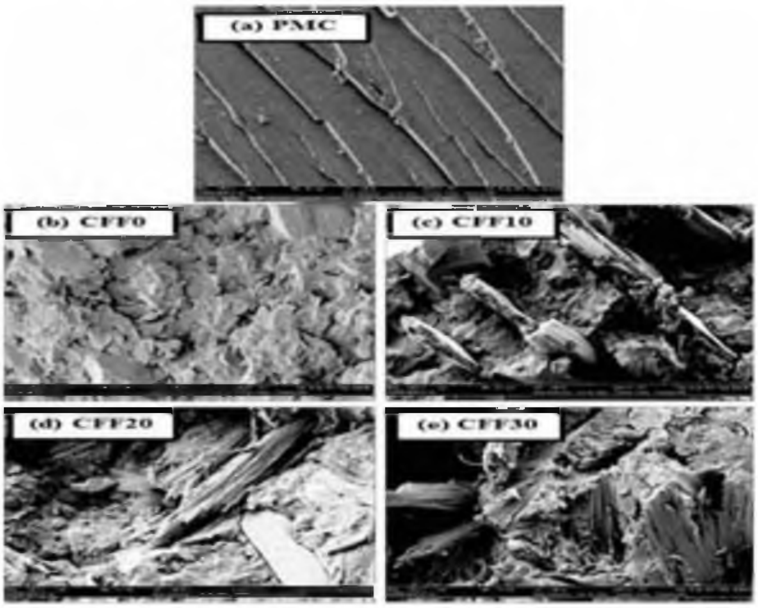


**FIGURE 4**
**SEM images for fracture surfaces matrix composite (a) and chicken feather composites with different weight % (b to e) captured at 5.00kx magnification**

## CONCLUSIONS

There are many factors that can influence the performance of natural fiber reinforced composites. Apart from the hydrophilic nature of fiber, the properties of the natural fiber reinforced composites can also be influenced by fiber content and/or amount of filler. The results demonstrate the reinforcing effect of animal-based fiber on polymer matrix. It also reveals that composite with in-creasing amount of feather fiber provided also better physical and chemical properties as com-pared with marble powder polymer composite. If the poultry waste can be utilized and used any engineering applications, they will be preferred due to low-cost and superior characteristics and the most importantly they will not cause ecological and health problems anymore. It can be concluded that either the increasing of CFF or decreasing of waste marble dust reinforced composite have potential applications due to its improved the flexural pro-perties but not impact behavior. Another way to enhance the composite properties and produce a crosslink surface morphology should be applied different resin or to eliminate lack of adhesion between matrix and fillers with the effective treatments.

The mechanical and physical test results of the polymer composite with reinforced mixture ratio as 30:70 (wt %) of feather fiber/waste marble powder is obtained; light, water resistant, easy to use (stacks slide easily), eco-friendly, reusable (washable) material. Overall, the CFF composites can be potentially used in poultry industry to manufacture egg trays for transportation and storage of eggs.

## REFERENCES

[1] Gopinath, A., Kumar, S. and Elayaperumal, A. (2014) Experimental Investigations on Mechanical Properties of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices. 12th Global Congress on Manufacturing and Management (GCMM – 2014), Procedia Engineering, 97(2014), 2052-2063.

[2] Barone, J.R. and Schmidt, W.F. (2005) Polyethylene reinforced with keratin fibers obtained from chicken feathers. Composites Science and Technology, 65, 173-181.

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

[4] Zhan, M., Wool, R.P. and Xiao, J.Q. (2011) Electrical properties of chicken feather fiber reinforced epoxy composites. Composites Part A, 42, 229-233.

[5] Cheng, S., Lau, K., Liu, T., Zhao, Y., Lam, P. and Yin, Y. (2009) Mechanical and thermal properties of chicken feather fiber/PLA green composites. Composites Part B, 40, 650-654.

[6] Adetola, S.O., Yekini, A.A. and Olayiwola, B.S. (2014) Investigation into Physical and Mechanical Properties of Few Selected Chicken Feathers Commonly Found In Nige-ria. Journal of Mechanical and Civil Engi-neering, 11, 45-50.

[7] Jagadeeshgouda, K.B., Reddy, P.R. and Ishwaraprasad, K. (2014) Experimental Study of Behaviour of Poultry Feather Fiber- A Reinforcing Material for Composites. IJRET: International Journal of Research in Engineering and Technology, 3, 362-371.

[8] King'Ori, A.M. (2012) Management of Poultry Processing By-Products - Utilization of Feathers. International Journal of Livestock Research, 2, 58-64.

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

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

[11] Amieva, E.J.C., Velasco-Santos, C., Martinez-Hernandez, A.L., Rivera-Armenta, J.L. and Mendoza-Martinez, A.M. (2015) Composite from chicken feathers quill and recycled polypropylene. Journal of Composite Materials, 49, 275-283.

[12] Uzun, M., Sancak, E., Patel, I., Usta, I., Akalin, M. and Yuksek, M. (2011) Mechanical Behaviour of chicken quills and chicken feather fibres reinforced polymeric composites. Inter-national Scientific Journal, 52, 82-86.

[13] Ghani, S.A., Tan, S.J. and Yeng, T.S. (2013) Properties of Chicken Feather Fiber-Filled Low-Density Polyethylene Composites: The Effect of Polyethylene Grafted Maleic Anhydride. Polymer-Plastics Technology and Engineering, 52, 495-500.

[14] Song, N., Jo, W., Song, H., Chung, K.S., Won, M. and Song, K.B. (2013) Effects of plasticizers and nano-clay content on the physical properties of chicken feather protein composite films. Food Hydrocolloids, 31, 340-345.

[15] Wechsler, A., Ramirez, M., Crosky, A., Zaharia, M., Ballerini, A. and Nunez, M. (2011) Sustainable Furniture Panel Composites from Forestry and Food Industry. 1st Inter-national Conference on Engineering, Designing and Developing the Built Environment for Sustainable Wellbeing, Brisbane, Conference proceedings eddBE 978-0-98-05827-4-1.

[16] Winandy, J. E., Muehl, J.H., Glaeser, J.A. and Schmidt, W. (2007) Chicken Feather Fiber as an Additive in MDF Composites. Journal of Natural Fibers, 4, 36-48.

[17] Song, N.B., Lee, J.H., Mijan, M.A. and Song, K.B. (2014) Development of a chicken feather protein film containing clove oil and its application in smoked salmon packaging. LWT-Food Science and Technology, 57, 453-460.

[18] Celik, M.Y. and Sabah, E. (2008) Geological and Technical Characterization of Iscehisar (Afyon-Turkey) Marble Deposits and the Impact of Marble Waste to Environmental Pollution. Journal of Environmental Management, 87, 106-116.

[19] Hamza Rania, A., El-Haggar, S. and Khedr, S. (2011) Utilization of Marble and Granite Waste in Concrete Bricks. International Journal of Bioscience, Biochemistry and Bioinfor-matics, 1 (4) 286-291.

[20] Sakalkale, A.D., Dhawale, G.D. and Kedar, R.S. (2014) Experimental Study on Use of Waste Marble Dust in Concrete. International Journal of Engineering Research and Appli-cations, 4(10), 44-50.

[21] Pathan, V.G. and Pathan, G. (2014) Feasibility and Need of use of Waste Marble Powder in Concrete Production. Journal of Mechanical and Civil Engineering, e-ISSN: 2278-1684: 23-26.

[22] Guru, M., Tekeli, S. and Akin, E. (2007) Manufacturing of Polymer Matrix Composite Material Using Marble Powder and Fly Ash. Key Engineering Materials, 336-338, 1353-1356.

[23] Baba, B.O. and Ozmen, U. (2015) Preparation and mechanical characterization of chicken feather/PLA composites. Polymer Composites,

DOI 10.1002/pc.23644, 2015, online. ISSN: 1548-0569.
[24] Acda, M.N. (2010) Waste Chicken Feather as Reinforcement in Cement-Bonded Composites. Philippine Journal of Science, 139, 161-166.
[25] AOAC, Official Methods of Analysis of The Association of Official Analytical Chemists, 17th Ed., (2002) Editor; William Horwitz, Current Revision 1.
[26] Tseng, F.C.J, Verbeek, C.J.R. (2011) Biofibre production from chicken feather. SCENZ-IChemE annual conference 2011 New Zealand, 1-2 December.
[27] Schmidt, W.F. (2001) Micro-crystalline keratin: from feathers to composite. Symposium U-Advanced Fibers, Plastics, Laminates and Composites, MRS Online Proceedings Library (OPL), 702.
[28] Reddy, K.N., Chanrasekar, V., Thirupathi, R.K. and Hussain, S.A. (2014) Performance Evaluation of Emu Feather Fiber Reinforced Polymer Composites. The International Journal of Mechanical Engineering and Robotic Research, 3(1), 272-284.
[29] El-Hinnawi, E. and Abayazeed, S.D. (2011) Characterization of Dimension Stone Sawing Sludge in Egypt. Journal of Applied Sciences, 11, 1019-1025.
[30] Goyal, S.S. (2006) Silanes: Chemistry and applications. Journal of Indian Prosthodontic Society, 6, 14-18.
[31] Oladele, I.O., Olajide, J.L. and Ogunbadejo, A.S. (2015) The Influence of Chemical Treatment on the Mechanical Behaviour of Animal Fibre-Reinforced High Density Polyethylene Composites. American Journal of Engineering Research, 4, 19-26.
[32] Winandy, J.E., Muehl, J.H., Micales, J.A., Raina, A. and Schmidt, W. (2003) Potential of Chicken Feather Fibre in Wood MDF Composites. Proceedings of the 2nd Eco-Composites Conference, P.20, Queen Mary, University of London, September 1-2, 2003, 1-6.
[33] Rao, V.A., Satapathy A. and Mishra S.C. (2007) Polymer composites reinforced with short fibers obtained from poultry feathers. Proceedings of International and INCCOM-6 Conference Future Trends in Composite Mate-rials and Processing, December 12-14, Indian Institute of Technology Kanpur.
[34] Ayrilmis, N., Kaymakci, A. and Ozdemir, F. (2013) Physical, mechanical, and thermal properties of polypropylene composites filled with walnut shell flour. Journal of Industrial and Engineering Chemistry, 19, 908–914.
[35] Arrakhiz, F.Z., Achaby, M.E.L., Benmoussa, K., Bouhfid, R., Essassi E.M. and Qaiss, A. (2012), Evaluation of Mechanical and Thermal Properties of Pine Cone Fibers Reinforced Compatibilized Polypropylene. Materials and Design, 40 (2012), 528–535.

**Received:** 08.09.2016
**Accepted:** 09.02.2017

**CORRESPONDING AUTHOR**

**Alev Akpinar Borazan**
Bilecik Seyh Edebali University
Faculty of Engineering
Department of Chemical and Process Engineering
Bilecik, 11210 – TURKEY

E-mail: alev.akpinar@bilecik.edu.tr

T.C.
BİLECİK ŞEYH EDEBALİ ÜNİVERSİTESİ
Fen Bilimleri Enstitüsü Müdürlüğü

Sayı :59931009-399/
Konu :Lisansüstü Öğrenci Danışmanlığı

Sayın Dr. Öğr. Üyesi Alev AKPINAR BORAZAN
Öğretim Üyesi

İlgi : 12/10/2018 tarihli, 5088 sayılı yazı.

Enstitümüz Kimya Mühendisliği Anabilim Dalı ortak lisansüstü programı aşağıda listelenen öğrencilerinin tez danışmanlığı Üniversitemiz Öğretim Üyesi Dr. Öğr. Üyesi Alev AKPINAR BORAZAN tarafından yürütülmektedir. Öğrencilere ait tez bilgileri aşağıda belirtilmiştir.

Bilgilerinizi ve gereğini rica ederim.

**e-imzalıdır**
Dr. Öğr. Üyesi Oğuzhan DEMİR
Müdür a.
Enstitü Müdür Yardımcısı

| T.C. Kimlik No | Adı-Soyadı | Prog. | Danışman Atanma Tarihi | Tezin Adı | Öğrencinin Durumu |
|---|---|---|---|---|---|
| 30307265994 | Banu YOKUŞ | YL | 02/01/2012 | Farklı Ön İşlemelerin ve Uygulanan Farklı Kurutma Yöntemlerinin Elmada Toplam Fenol Miktarı ve Antioksidan aktivite Üzerine etkileri | Mezun (04/09/2014) |
| 31813229470 | Reyhan HEYACAN | YL | 17/07/2014 | Hazır Yemek Sisteminde Kalite ve Maliyete Bağlı Üretim Giderlerinin Matematiksel Analizi | Mezun (18/07/2016) |
| 14896158844 | Gözde BUĞDAYCI | YL | 10/07/2015 | Çay ve Yumurta Kabuğu İlavesinin Kompost Oluşumuna Etkisi ve Kompost Karakterizasyonu; Bilecik Şeyh Edebali Üniversitesi Uygulama Örneği | Mezun (29/06/2016) |
| 31615548250 | Murat YILMAZ | YL | 04/02/2015 | Buğday/Çavdar/Bamya Kompozit Ununun Ekmeğin Bazı Kalite Özelliklerine Etkisi | Mezun (22/08/2017) |
| 22390540140 | Günce ALP ADIGÜZEL | YL | 04/02/2015 | Kestane Kabuğu ve Cam Lifi Takviyeli Hibrit Kompozit Üretimi ve Karakterizasyonu | Aktif |
| 30019987658 | Duygu GÖKDAİ (Duygu KURU) | DR | 24/05/2016 | Cam Malzemelerinin Daldırma Yöntemiyle Bor Nitrür İnce Filmle Kaplanmasının Araştırılması | Aktif |



Bilecik Şeyh Edebali Üniversitesi Rektörlüğü 11030 Bilecik
Tel: : 0228 214 11 31-36-38-39 Faks: 0228 214 11 32
E-Posta: : fbe@bilecik.edu.tr Elektronik ağ:fbe.bilecik.edu.tr
Ayrıntılı bilgi için irtibat: