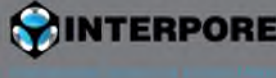
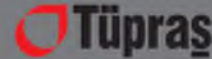
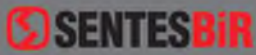


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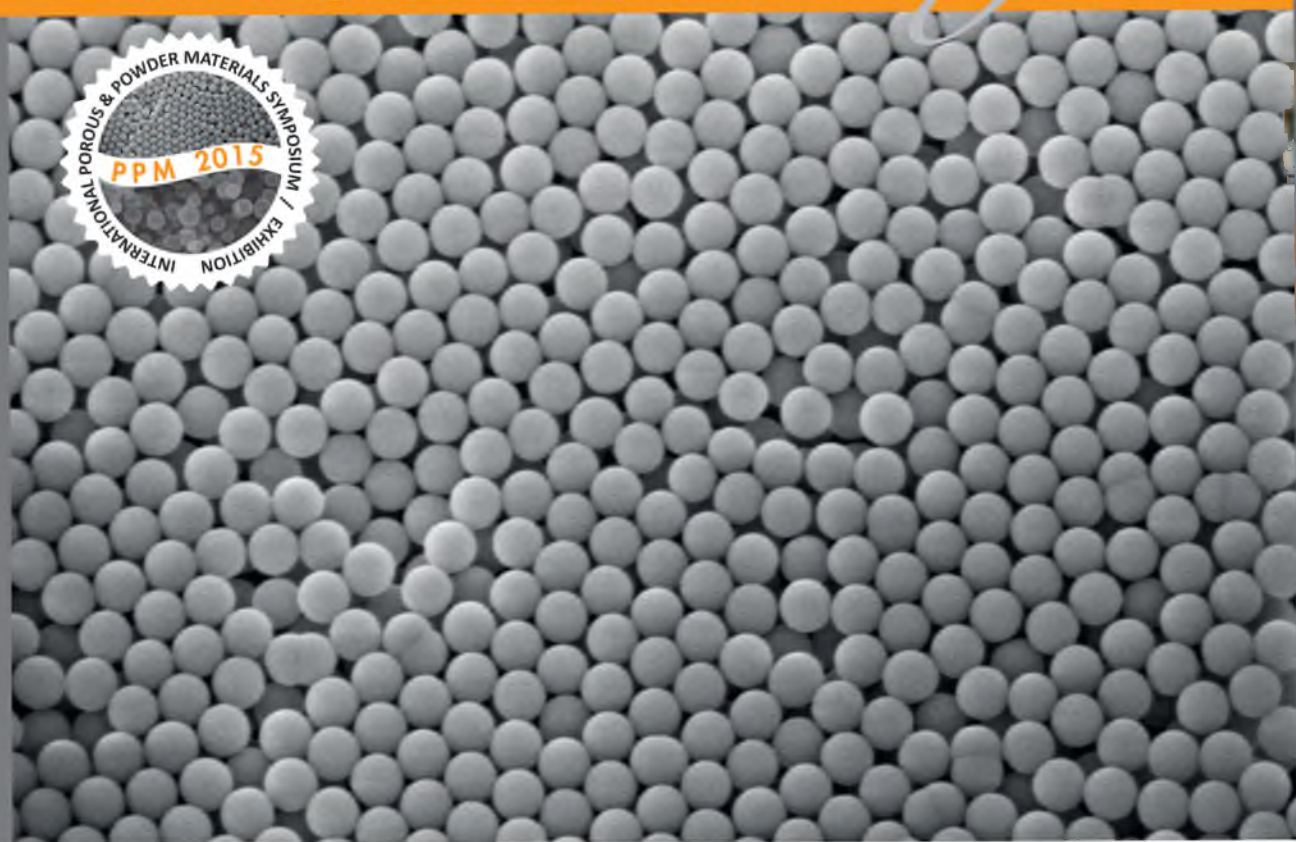
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MANUFACTURING POLYMER COMPOSITES REINFORCED WITH POULTRY FEATHERS AND MECHANICAL PROPERTIES

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ABSTRACT: In the last years, there has been an increasing interest in using natural materials as reinforcements in polymeric composites. This is not only for environmental reasons but also for their properties and sustainability. Chicken feathers are a waste by product of the poultry industry, with more than 4.10^6 ton worldwide annually produced. The feather waste is usually disposed by either subjected for burning or landfill, which is considered as expensive process and not environmentally friend. The proposal solution is to utilize chicken feather as reinforcements in composites to offer environmental and economical solution for feather disposal. This work was carried out to investigation the possibilities of utilizing animal fibers as reinforcement in polymeric materials. For the determination of the chemical properties of chicken feathers was carried out according to AOAC standard. Physical and mechanical properties such as thickness swelling, water absorption, tensile strength, flexural modulus, hardness etc. were evaluated. Preferable values were obtained with reinforced mixture ratio as 30:70 (wt %) of feather fiber/marble dust in the polymer composites.

Keywords: Physical and mechanical properties, polymer composite, chicken feather, waste

1. INTRODUCTION

There has been recent interest in developing composites based on short-fibers obtained from agricultural resources. These organic fibers are usually of lower density than inorganic fibers, environmentally friendly, and relatively easy to obtain (Barone et.al., 2005). 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. 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 (Cheng

et.al., 2009). There are very few studies detailing composites made from protein

Fibers obtained from agricultural resources. Composite materials have been prepared from poultry feather fiber. The unidirectional chicken feather fibers reinforced composites were produced with vinyl ester and polyester resins with three fiber reinforcement loadings (2.5, 6, 10wt%) by Uzun M. et.al. (2011). Chicken feather fiber (CFF)/reinforced poly(lactic acid) (PLA) composites were processed using a twin-screw extruder and an injection molded by Cheng et.al. (2009). Mechanical and acoustical properties of composites from ground chicken quill and polypropylene (PP) have been investigated and compared with jute-PP composites. A functional composite of

ground poultry quill may potentially lead to significant reduction of environmental pollution through replacement of nonrenewable materials in composites by Huda and Yang (2008). In this study it was carried out to investigation the possibilities of utilizing animal fibers as reinforcement in polymeric materials.

2.MATERIALS AND METHODS

2.1 Materials

Polyester has been used as a matrix material. Marble powder and waste chicken feathers received from the company are used as a reinforcing material at different rates. Cobalt as accelerator, ButanoxAkzo M60 as hardener was used to produce composite materials.

2.2.Pretreatment

A pre-treatment was required to stabilize and transform chicken feathers into a stable technical material. 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, quill was separated from barbs and cut into small pieces. Finally last drying was again in oven at 105°C, 2hours. Feather fiber moisture was decreased to %10. Dried and chopped feathers and also marble pieces then ground into powder form (0.425 µm) using a laboratory Mill Pulverisette 9, (Fritsch, Germany) (Fig1.).



Figure 1. Waste a) chicken feathers and powder b) marble powder

2.3. Composite Material Manufacturing Process

The polyester matrix was compounded, respectively, with reinforcement fillings in different ratios by weight. The raw material formulations, which are given per the mass proportion in percentage, used for the composites are presented in Table 1.

Table 1. Ratio of waste material used for composite manufacture to be recycled

Code	Marble powder (*wt %)	Chicken feather (*wt %)
PMK	0	0
FFM0	100	0
FFM10	90	10
FFM20	80	20
FFM30	70	30

*Weight Percent [wt%]

The reinforcement material and polyester resin was first mixed in the indicated ratios. After then, performed using a speed of 500, 1000 and 1500 rpm (Stuart scientific mechanical stirrer), 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 (Fig 2). Curing condition for composites were 105°C, 1 hour in an oven (Binder, Germany).

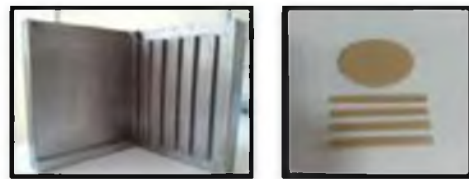


Figure 2. Mold and composite samples

2.4. Chemical, Physical and Mechanical Testing

Proximate composition of feather samples was analyzed according to AOAC standard. Moisture was determined by the official gravimetric AOAC method (AOAC 945.21). Samples

were dried to constant weight in an air oven at $(105 \pm 5) ^\circ\text{C}$ and weight loss on drying was expressed as moisture content (%). Ash content was determined by direct gravimetric method (AOAC 923.03) in an oven at $550 ^\circ\text{C}$ until constant weight was attained. Crude proteins (CP) content was estimated based on total nitrogen content of samples determined by Kjeldahl method, using applicable converting factor, 6.25 based on total nitrogen content of the proteins in major compound of selected composite food. Crude fat content was determined gravimetrically following Soxhlet extraction, with ether according to the official AOAC method (AOAC 920.39)

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, thickness swelling (TS) and water absorption (WA). These tests were carried with test sample sizes of 5×5 cm. The density was measured using a gas pycnometer, Micromeritics the AccuPyc II 1340 model. Water absorption was determined from the measured weight gain 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 (Wechsler et al., 2011).

Flexural testing was conducted using the three point bend test according to EN ISO 178 TS 985 to determine the modulus of elasticity (MOE). Tensile testing was conducted using a 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. Five replicate samples of each composite were used for each test. The

flexural test specimens were also cut from the composite panels with dimensions of $100 \text{ mm} \times 10 \text{ mm} \times 4 \text{ mm}$; length, width and depth, respectively. The bending measurements were also performed at the ambient conditions of $23 \pm 2 ^\circ\text{C}$. 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. 8cm in diameter to penetration of a spring loaded needle-like indenter. Five replicates of each composite formulation were tested to determined averaged hardness.

The fracture surfaces of the flexural test specimens were characterized with high resolution field emission scanning electron microscopy (SEM, Zeiss Supra 40VP, Germany). The specimens were coated with platinum and examined at 20 kV accelerating voltage. Samples of image analysis and SEM study were prepared from the edges of the three point bending test specimens.

3. RESULTS AND DISCUSSIONS

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

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

The chicken feathers presented high protein content. Acta (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 (Tseng et al., 2011; Acta 2010; Schmidt 2002).

The results for the density, TS and WA of the composite samples are presented in Tab. 3. The densities of the composites with the four different filler ratios are higher than the density of the matrix polymer (PMK).

Only minimal differences are evident amongst the four composites.

Table 3. Density, thickness swelling and water absorption of composite samples

Composite code	Density, (g/cm ³)	TS, 24 hours (%)	WA, 24 hours (*wt %)
PMK	1.1892±0.0004	0.68	0.18±0.03
FFM0	1.7741±0.0010	-0.49	2.44±0.08
FFM10	1.7421±0.0008	-0.14	0.29±0.02
FFM20	1.6680±0.0005	0.31	0.35±0.14
FFM30	1.6330±0.0004	0.07	0.55±0.24

*Weight Percent [wt%]

The thickness swelling results for the composites are also very different to that for PMK, with values ranging from -0.48 to 0.30%. The filler dispersion ratio chosen in the FFM0 and FFM1 are respectively 100% and 90% marble powder. TS values of these composites are negatively. Two reasons should be effectively on the results; firstly, marbles are calcareous metamorphic rocks. Their main component is calcite, a mineral formed of calcium carbonate CaCO₃, 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 (El-Hinnawi et.al.2011). Secondly, coupling agent was not be used in the manufacturing. Unfortunately, strongly chemical bond did not provide between two dissimilar materials, feather fiber (organic) and marble powder (inorganic). FFM30 had the lowest swelling of 0.069%. The water

absorption of the composites was 0.29±0.02-2.44±0.08 wt% compared with 0.18±0.03wt% for the unfilled matrix material (PMK). Amongst the composites, FFM10 had the lowest water absorption of 0.29±0.02wt%, which has approximately minimum ratio feather and barb quantities. A feather barb is the lateral fiber branching (in parallel rows on the shaft. The 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 (Fig. 3).

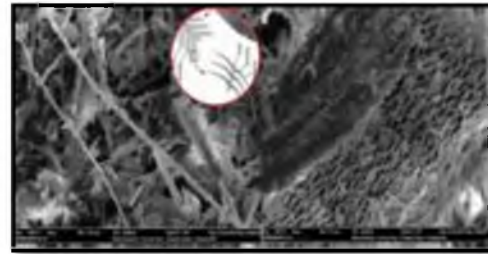


Figure 3. Microstructures of the chicken feathers and zoom into barb images. The mechanical properties test results are given in Tab 4.

Table 4. Test results of composite samples force, modulus of elasticity, tensile strength

Composite code	Force (N)	Modulus of elasticity (GPa)	Tensile strength (N/mm ²)
PMK	146.875	3.57	69.58
FFM0	107.5	8.44	48.65
FFM10	116.875	7.83	54.07
FFM20	112.5	7.47	51.06
FFM30	137.5	6.55	63.84

The tensile strength of the composites was 48.65-63.84(N/mm²), and was substantially lower than the values obtained for and 69.58(N/mm²). The values for the composites made without feathers, FFM0 had the lowest tensile strength (48.65N/mm²) but the highest MOE (8.44GPa) while the FFM30 had

the highest tensile strength with maximum ratio feathers material having the lowest modulus of elasticity. The modulus of elasticity was generally higher for the composites than for the unfilled polyester for which a value of PMK of 3.57GPa was obtained.

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 ± 0.43 to 85.25 ± 1.09 . According to hardness test, increasing of chicken feathers ratio into manufacture was caused to be decreasing to the hardness of composites (Fig. 4).

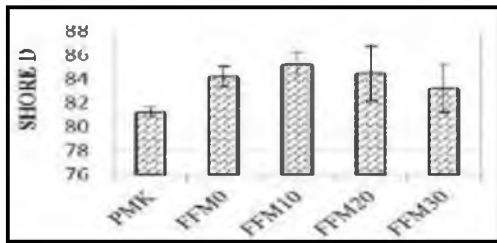


Figure 4. Relationship between the filling ratio and hardness of polymer composite samples

The SEM was operated to determine their fracture surface, microstructure, and fiber orientation characteristics.

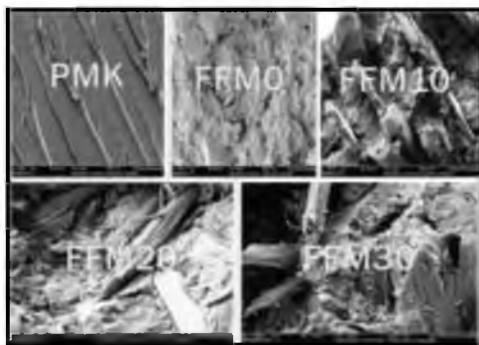


Figure 5. Images showing structure of polymer composite samples captured at 5.00kx magnification

4. 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 / amount of filler. The results demonstrate the reinforcing effect of animal-based fiber on polymer matrix. It also reveals that composite with increasing amount of feather fiber provided also better physical and chemical properties as compared with marble powder polymer composite. To wider the applications of these fibers in solving environmental problems, more studies have to be continued in the future.

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