IOP Conference Series: Materials Science and Engineering

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To cite this article: N Paayev *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **254** 192013

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Investigation some characteristics of chicken feather's rachis

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Abstract: In recent years, obtaining the natural protein fibers from chicken feathers, which are obtained as a by-product in the production of chicken meat and which cause environmental pollution and important part is waste, has been drawn to the perspective of scientists. So, the investigations about the chicken feather fibers reveal important properties of these fibers. Chicken feather fibers are obtained by mechanical cutting of the barbs which have fibrous structure, the structure branched from rachis and constitute the body of the feather. The rachis part of chicken feather constitutes approximately half of the weight of the feathers. So, it is necessary to examine the properties of the chicken feathers in order to gain their industrialization. This study is concerned with the mechanical and physical properties of the material that is taken as a by-product in the production of fibers from chicken feathers and constitutes the rachis part of the feathers.

1. Introduction

In recent years, the perspective of obtaining the natural protein fibers from chicken feathers which are obtained as a byproduct in the production of white meat and the important part is waste and causes environmental pollution, attracts the attention of scientists. Investigations on chicken feather fibers reveal important properties of these fibers [1]-[4]**.** Chicken feather fibers are obtained by mechanical cutting of barbs (fibrous structure), which are extended from rachis. But today, technology of fiber production from chicken feathers is not available. Such a technology is being developed at Erciyes University (Turkey). In the production of fibers from chicken feather with using special machine, the rachis part of feather is seperated from this part of the barbs.

Chicken feather barbs constitutes approximately half of the weight of the feathers. This means that industrialization of chicken feathers should be considered about the part of the rachis. In this study, some properties of this material were examined.

2. Experiment

2.1. Material

The material of chicken feather's rachis used in this study was taken from "Tad Piliç" company and obtained this chicken feathers at Textile Engineering Department in Erciyes University. The chicken feathers obtained from farm were washed at 40°C with washing matter, which has a dirt and grease remover specialities, and sodium hypochlorite(NACIO) in terms of not damaging the fibers. After the water of feathers was taken in the centrifuge, the feathers were dried at a temperature of 40°C in a laboratory-type feather dry machine at Erciyes University Department of Textile Engineering and disinfection was applied for 12 minutes at 70°C temperature. The dried feathers were subjected to the process of separation from the rachis part of the barbs part. Separated fibers and barbs were collected separately (**Figure 1**).

2.2. Method

Sem analyze

One of the important features of the chicken feather's rachis material is related to the internal structure of this material. The Leo440 Scanning Electron Microscope(SEM) at Erciyes University Technology Research and Application Center was used to analyze the internal and surface of rachis. The rachis was obtained with separation of barbs was cutten precisely with the help of a sharp razor

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on a glass plate in transverse and longitudinal directions and affixed on metal plates with double sided tape. Samples were subjected to SEM analysis.

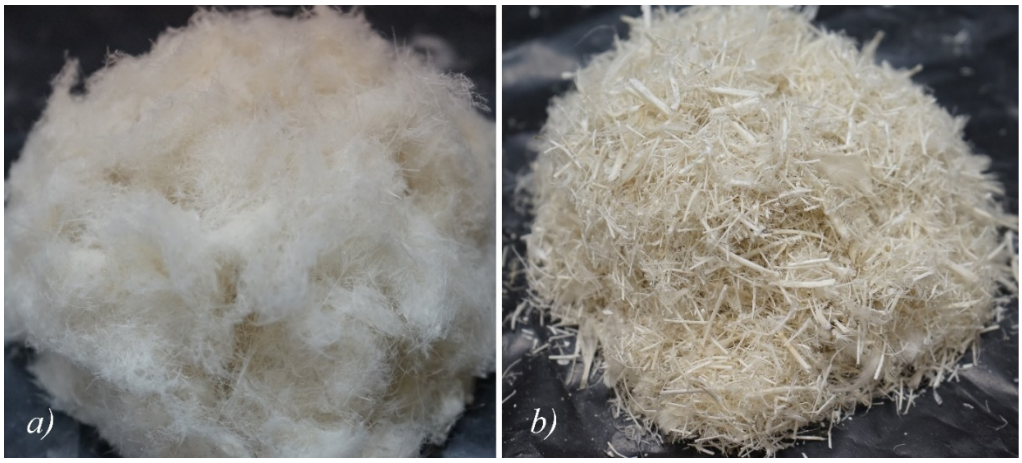

Figure 1. Fiber (*a*) and rachis (*b*) materials taken in chicken feather fiber production

Mechanical properties of chicken feather's rachis

Chicken feather is very different in terms of content of rachis material. Thus, the parts of the rachis are very different according to their thickness and length and this situation affects their mechanical properties. In order to investigate the mechanical properties of chicken feather's rachis material, tensile tests were applied to rachis samples at Erciyes University Technology Research and Application Center. For the test, 14 rachis samples with a length over 2cm were taken and their thicknesses were measured. The thickness of the sample was measured at three points: both ends and midpoints of samples were measured with calipers and obtained average value and numbered the samples. Tensile tests were applied for each sample and all data were taken to the table.

Investigation of the hygroscopic properties of the samples

The hygroscopic properties of the rachis samples obtained from chicken feather were investigated as the dehumidification and water absorption properties of the samples.

Investigation of the getting moisture ability of chicken feather's rachis from air

An experimental study was conducted to investigate the getting moisture ability of chicken feather's rachis and the weighing method was used to determine the moisture content of the rachis. The ambient temperature and the relative environment humidity were chosen as the independent changing factors in the study. The levels of change of the factors are given in Table 1.

Table 1. Test conditions for examining the getting moisture ability of chicken feather rachis from air

Independent changing factors	**Change levels of factors**		
Environment temperature, ºC	20	40	60
Relative environment humidity, %	65	80	95

For using in the experiments, the 3gr sample was taken from rachis mass, which was conditioned for 2 hours at 20°C temperature and 65% relative humidity. The samples were weighed for 2 hours under the conditions specified in the test plan and the weights of the samples were determined by weighing and the results were written to the table. The moisture of the fiber sample which was kept for 2 hours under the determined environment conditions according to the test plan was evaluated in terms of the dry weight of the sample in percent, as following the formula:

$$W = \frac{m_w - m_d}{m_d}$$

In this formula, W - moisture content sample according to dry weight - (%), m_{wet} - wet weight of sample (g), m_{dry} - dry weight of sample (gr).

To determine dry weight of fiber sample were kept under normal conditions (20°C temperature and 65% relative humidity) for 2 hours and taken 3g fiber from sample. Then, this fiber was kept for 120 minutes at 105°C. At the end of the period, rachis mass was measured and the sample dry weight was found to be 2,72gr.

The moisture that chicken feathers get from the air was determined by weighing by keeping under the different environmental conditions specified in Table 1 and the percent of dry weight of the sample was calculated and the results were written to the table. For the test results, two-directional ANOVA was applied with Minitab 17 program package.

Investigation of water absorption ability of chicken feather's rachis

Water-soaked chicken feather's rachis were tested to determine how much water was retention of structure. To determine water absorption properties of chicken feather rachis, the "Water Immersion Method" was based on which is proposed by the standard of TS 866 "Determination of Water Absorption Properties of Cotton Textile Products". Because of the material to be tested, chicken feather's rachis is not a standard material, it has to adapt to the standard's requirements to the test object. Test samples were prepared as follows: samples were conditioned according to TS 240 and weighed 3g and placed in the sample bag. During the experiment, the special experimental setup, it was prepared to immerse the samples in the water. The fibers, which was weighed as 3gr, were placed in the strainer apparatus, and the apparatus was placed in a 2lt glass beaker. Distilled water, which was a 21±3°C, was added to the beaker. Filter apparatus was designed so that it can be hanged in the middle of the beaker. The apparatus was suspended in water and the stopwatch was turned on by placing it in a test cabinet designated for the required level of temperature. At the end of the 30, 90, 150 minutes' period, the apparatus was removed from the water, and it was suspended for 10 minutes in order to remove the water, which is mechanically related to the rachis by filtration. The sample was weighed on the precision scale.

At the end of the experiment, the values, which are related the weight of the weighed fibers, were written in table. The experiment was repeated at 20°C, 40°C, and 60°C temperature for each rachis. New rachis was used for each time.

For the test results, two-directional ANOVA was applied with Minitab 17 program package. For the independent variables, water temperature and water immersion time were accepted (Table 2).

Table 2. Test conditions for examining the ability of rachis samples to remove moisture from air

Independent changing factors	**Change levels of factors**		
Water temperature, °C	20	40	60
The water's remaining time in the water, minute	30	90	150

3. Result and Discussion

Structural properties of chicken feather's rachis material

The length of the rachis material obtained from the chicken feather is variable. For crude feathers, rachis size is the length of the feather. However, since rachis is broken during the fiber Production from feathers, this length varies widely. In our studies, the length of the rachis pieces ranged from 5 to 60mm and the thickness ranged from 0,5 to 1,8mm.

The tensile test results applied to the chicken feathers' rachis samples are shown in Table 3. For the test, 14 sample was taken and applied to the tensile test and the breaking strength, the breaking

extension and elastic modulus values are written in accordance with thickness values of the samples. As can be seen here, there is a close relationship between the tensile strength and the thickness of the rachis material. The mean values of the mechanical properties are given in Table 3.

Table 3. Tensile test results applied to chicken feather rachis

Sample	Diameter of rachis sample, 10^{-3} m	Max Strength, N	Max Extension, %	Elasticity modulus, 100·MPa
1	1,25	45,81	4,88	9,96
2	1,33	64,66	8,44	8,04
3	1,07	27,06	3,79	8,77
4	1,32	54,62	7,51	10,76
5	1,40	76,25	9,79	8,14
6	1,69	82,71	5,01	10,17
7	1,52	80,83	9,17	8,23
8	1,37	59,70	7,22	9,01
9	1,47	73,23	10,19	8,23
10	1,34	56,58	4,68	11,40
11	1,22	37,34	4,55	9,07
12	1,39	39,33	3,39	8,94
13	1,12	34,56	5,22	9,33
14	1,16	37,48	3,67	11,65
Average value	1,33	55,01	6,25	9,41

The specific weight of chicken feather material is known as 0,80g/m³ [2]. According to measurement of volumetric weight of rachis is 0,255g/m³ in our study.

One of the most important features of the feathers is that they are extremely light, which is due to the hollow structure of the feather material. Through SEM analysis, micro-porous microstructure of chicken feather bars and rachis were obtained and is was seen that this structure was similar to each other (Figure 2).

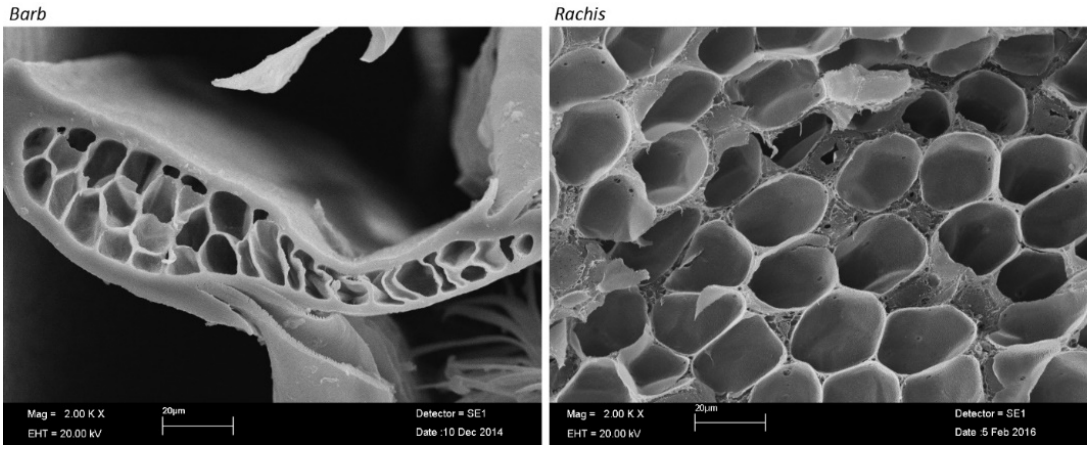

Figure 2. SEM images of the microcellular internal structure of chicken feather fiber and rachis

In **Figure 3**, SEM images of transverse and longitudinal sections of rachis samples are given. It has been revealed that the pores forming this structure are in the form of microcells with dimensions of 5…20 µm, which are closed on all sides.

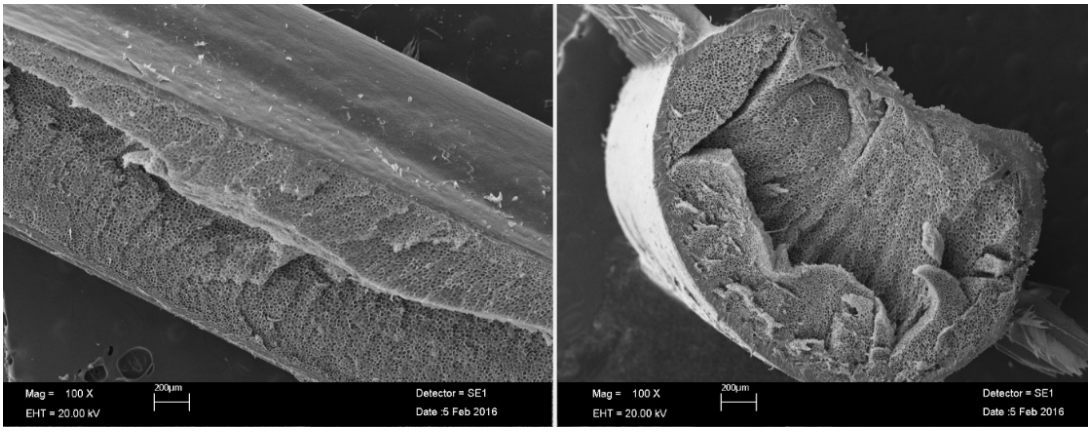

Figure 3. SEM images of longitudinal and cross section of chicken feather rachis

Examination of hygroscopic properties of chicken feather rachis

The experimental results of examination of the getting moisture ability of chicken feather's rachis are given in Table 4.

Table 4. Test results of dehumidification ability of rachis

Experiment number	Environment temperature, °C	Relative humidity of the environment, %	Moist weight of rachis mass, gr	The moisture content of the sample according to dry weight, %
1		65	3,00	10,29
2	20	80	3,16	16,18
3		95	3,20	17,65
4		65	3,07	12,87
5	40	80	3,08	13,24
6		95	3,25	19,49
7		65	2,86	5,15
8	60	80	2,94	8,09
9		95	3,04	11,76

For the values in Table 4, two-directional ANOVA was applied with Minitab 17 program package and results were written to the Table 5*a*. According to these results, the moisture content of the sample for different humidity and temperature environment is significant.

In **Figure 4*a***, graphical curves are given which express the between the moisture content of test samples according to the dry weight and relative humidity of environment.

As can be seen from these curves, the ability of rachis to absorb moisture from air varies according to environment conditions. Amount of moisture the material is receiving from the air increase with the increasing of relative humidity of environment. This increase continues until 40°C.

At the temperature of 60°C, humidity of the rachis from the air is lower than the humidity rate of 20°C and 40°C temperature. This is a result of the activation of water molecules by increasing the temperature. As the humidity increases, dissolved bonds among the macromolecules increase. As the environment humidity increase, the rachis continues to take moisture from the air. However, as the water molecules become more active by increasing the temperature, the moisture amount of rachis is not much.

Examination of water absorption ability of chicken feather rachis

Water absorption test results of water-dipped chicken feather's rachis are shown in Table 6. İn Table 5*b* gives the variance analysis applied to these results. In Figure 4*b*, according to the table values, when compared the water amount of rachis material according to dry weight with water immersion time of samples, the graphical curves are given. These curves show that water absorption ability of rachis material changes according to water absorption time and water temperature in a certain way.

Table 5. ANOVA tables of dehumidification test results of rachis

a

General Linear Model: HRS versus RHE; ET

Method

Factor coding (-1; 0; +1)

Factor Information

Factor	Type	Levels	Values
RHE	Fixed	3	65; 80; 95
ET	Fixed	3	20; 40; 60

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
RHE	2	75,725	37,8624	62,84	0,001
ET	2	76,598	38,2988	63,57	0,001
Error	4	2,410	0,6025		
Total	8	154,733			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,776216	98,44%	96,88%	92,11%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	12,338	0,259	47,68	0,000	
RHE					
65	-2,901	0,366	-7,93	0,001	1,33
80	-1,061	0,366	-2,90	0,044	1,33
ET					
20	1,142	0,366	3,12	0,035	1,33
40	2,862	0,366	7,82	0,001	1,33

Regression Equation

HRS = 12,338 - 2,901 RHE_65 - 1,061 RHE_80 +
+ 3,962 RHE_95 + 1,142 ET_20 + 2,862 ET_40 -
- 4,004 ET_60

b

General Linear Model: HRS versus WPS; T

Method

Factor coding (-1; 0; +1)

Factor Information

Factor	Type	Levels	Values
WPS	Fixed	3	30; 90; 150
T	Fixed	3	20; 40; 60

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
WPS	2	757,7	378,87	6,89	0,051
T	2	2528,2	1264,10	22,99	0,006
Error	4	220,0	54,99		
Total	8	3505,9			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7,41548	93,73%	87,45%	68,24%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	313,48	2,47	126,82	0,000	
WPS 30	11,64	3,50	3,33	0,029	1,33
90	-10,78	3,50	-3,09	0,037	1,33
T 20	0,12	3,50	0,04	0,974	1,33
40	20,47	3,50	5,85	0,004	1,33

Regression Equation

X = 313,48 + 11,64 Süre_30 - 10,78 Süre_90 -
- 0,86 Süre_150 + 0,12 Sic_20 + 20,47 Sic_40
- 20,59 Sic_60

Notes: HRS – Humidity ration of sample; RHE – Humidity of environment, ET – Environment Temperature,
WPS – The wetting period of the sample, T – Temperature

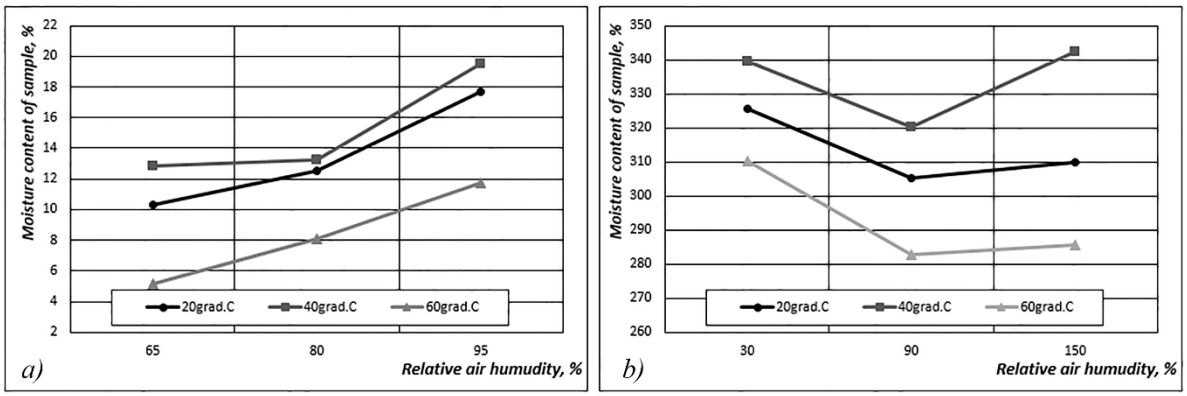

Figure 4. Changing in the rate of dehumidification in chicken feather rachis according to environment humidity

As can be seen from graphs in Table 5 and Figure 6, the amount of water retained in the structure of sample between 20-60°C temperature, which are tested to the getting water test for 30, 60, and 150 minutes, is decreasing at the first time with increased water-dip time in constant environment temperature.

The reason for this is that the rachis pores are initially filled with air and the water molecules have difficulty to reaching these pores. As the temperature increases, the pores which are abandoned by the air molecules are trapped with water molecules because of the increasing activity of the air molecules and water molecules and consequently water content in rachis increase. However, this situation changes over 40°C. Some of the water molecules, which are sufficiently activated, leave some pores. At 60°C, even if the process takes place at temperature like between 20 and 40°C, because of the high activity of the water molecules, rachis retains less water in structure.

Table 6. Test results of the water absorption capacity of rachis

Experiment number	Temperature, °C	The wetting period of the sample, minute	Wet weight of rachis, gr	The moisture content of the rachis according to dry weight, %
1		30	12,05	343,01
2	20	90	12,54	361,03
3		150	11,68	329,41
4		30	14,94	449,26
5	40	90	9,94	265,44
6		150	10,68	292,65
7		30	8,62	216,91
8	60	90	10,74	294,85
9		150	11,26	313,97

4. General Results

In this study, some properties of rachis material, geometric, mechanical and hygroscopic properties have been examined.

In our studies, the length of the rachis pieces ranged from 5 to 60mm and the thickness ranged from 0,5 to 1,8mm. The measured volumetric weight of rachis is 0,255g/m³. The average breaking strength of the rachis pieces is 55,01N, the maximum extension at break time is 6,25%, elasticity modulus is 941 MPa. The internal structure of rachis has been examined and it has been revealed that this structure is in the form of 5-20μm micro cells. These construction signifies the lightness and good insulation properties of rachis.

It has been found that the rachis material has high hygroscopy. The moisture absorbance ability of this material was investigated according to the environment temperature and the relative humidity of environment and there was a statistically significant relationship between these indicators. Rachis material has also water absorption properties. This characteristic of rachis was investigated according to water temperature and duration of interacting with water and it was found that there was a statistically significant relation between these parameters.

The results will allow for new areas for use rachis material.

Funding

This study was supported by The Scientific and Technological Research Council of Turkey (TÜBİTAK) with 115M725 numbered researching project.

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