JPPIPA 9(12) (2023)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Microstructure Characteristics of Chicken Feather Panels As An Alternative Wall Material

Ansarullah Faharuddin[1*], Mukhthar Thahir syarkawi[1], Juhana Said[1], Muhammad Zainal Altim[1], Zulkarnain Hamson[2], Siti Aisah[3]

[1] Faculty of Engineering, Universitas Muslim Indonesia, Makassar, Indonesia.
[2] Faculty of Communication, Universitas Indonesia Timur, Makassar, Indonesia.
[3] Management Science Study Program, Faculty of Economics and Business, Muhammadya University Makassar, makassar, Indonesia.

Received: October 17, 2023
Revised: November 29, 2023
Accepted: December 20, 2023
Published: December 31, 2023

Corresponding Author:
Ansarullah Faharuddin
ansarullah.ansarullah@umi.ac.id

DOI: 10.29303/jppipa.v9i12.6317

Abstract: Chicken feather waste, after being finely chopped, is converted into feather panels which can be an alternative material in architecture. Chicken slaughter waste produces 4-9% of live weight in the form of feathers, requiring technology to make it a renewable alternative material. This research aims to process chicken feather waste into alternative materials for room dividers and building walls, reducing environmental impacts. Scanning is carried out to analyze the surface characteristics of the panels before they are applied as environmentally friendly materials. Previous research recorded a chicken feather panel density of 0.38-0.4, categorizing it as a soft stiff fiberboard material. Experimental engineering methods and material scanning in the microstructure laboratory using SEM reveal surface topography and material composition. The test results show that chicken feather panels can be recommended as a new alternative material in architecture. This discovery has the potential to use chicken feather waste in a sustainable manner, providing an environmentally friendly alternative and reducing the burden on the environment. The integration of these materials can enrich innovation in sustainable construction.

Keywords: Alternative wall materials; Chicken feathers; Chicken feather panels; Micro structures

Introduction

Chicken feathers are one of the waste products of poultry livestock from industries or chicken slaughterhouses. The availability of chicken feather waste is so large that it can realistically be considered as the main ingredient for making panel materials. From literature data, it is found that for every chicken slaughtered, feathers are obtained as much as 6% of the live weight (Erlita et al., 2016), the slaughter age of the chicken ranges from 30 to 35 days with a slaughter weight of ± 1.5 kg (Ulupi et al., 2018), this data ensures that the availability and continuity The raw material for chicken feathers for the production of feather panels in the future is quite well maintained (Conzatti et al., 2013; Cruz et al., 2015). The large increase in chicken feather waste from chicken slaughterhouses can cause environmental pollution, so technology and methods are needed in processing chicken feather waste to reduce environmental threats so that it can be utilized by the wider community (Aranberri et al., 2017; Cheong et al., 2018; Mihăilă et al., 2020; Sari, 2015; Thyagarajan et al., 2013), can be used as raw material for biogas (Sumardiono et al., 2021).

The research was carried out in terms of research development as a sustainable and advanced alternative panel material in the field of architecture, related to the analysis of the topography and microstructure of chicken feather panels, before being applied to rafters as an alternative material.

Chicken feather waste that has been finely chopped and formed into feather panels makes it possible to be used as a new alternative material in the field of architecture (Azcune et al., 2016; Barone et al., 2005). The

How to Cite:
Faharuddin, A., syarkawi, M. T., Said, J., Altim, M. Z., Hamson, Z., & Aisah, S. (2023). Microstructure Characteristics of Chicken Feather Panels As An Alternative Wall Material. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12063–12072. https://doi.org/10.29303/jppipa.v9i12.6317

microstructural characteristics of chicken feather panels are identified before being applied as a new alternative material, in supporting the empowerment of renewable, economical and environmentally friendly materials (Gokce et al., 2017; Rekondo et al., 2014).

The research was carried out with the following objectives, namely that the chicken feather panels were characterized using a scanning electron microscope (SEM), before being applied as an alternative material in the field of architecture (Conzatti et al., 2013; Cruz et al., 2015).

The topographic method of chicken feather panels will be analyzed by scanning an electron microscope on the surface of the composite panel sample, determining the measurement concentration points with a carbon block stage and preparing samples from the determined points with an iron spatula that has been attached with a carbon tip and put in a box. Preparation in the SEM (Scanning Electron Microscopy) testing room, which previously carried out a coating process using the Smart Coater tool on the feather panel sample for ± 1 minute and then inserted the coated carbon tip block stage into the stage holder. After the coating process is complete and the sample has been inserted into the stage holder, the feather panel sample is ready to be analyzed using SEM (Scanning Electron Microscopy) to determine its morphology.

Research Significance/Problems

Research shows that chicken feather waste can be used as panel material and in the future it can become a renewable alternative material, with low cost, long lasting and contributes to reducing air pollution which is harmful to the environment (Hafez et al., 2023), thus involving a lot of mechanical equipment in the production process (Wijayanto et al., 2013). The potential application of chicken feather fiber as a polymer reinforcing material as a resin with a hollow protein fiber morphology (Bessa et al., 2017), as a new polymer material thereby influencing the physical, mechanical and thermal properties of biocomposite materials (Aranberri et al., 2018; Conzatti et al., 2013; Cruz et al., 2015).

We often encounter chicken feather waste and have not yet been utilized by many members of the public to use panel products as building materials in the field of architecture. In this research, chicken feather waste is formed into panels which will later be used by the community as building materials for walls or partitions. Research was carried out to identify the characteristics of chicken feather panels in analyzing the microstructure and topography of the panels before being used as a new alternative material in the field of architecture that is economical and friendly. Environment to realize the space design according to needs.

Method

Research to identify the characteristics of chicken feather panels in microstructure and panel topography tests was carried out in the laboratory of the Faculty of Engineering, Indonesian Muslim University, with several methods and stages including:

First, Prepare the test sample by determining the point that will represent the sample test material.

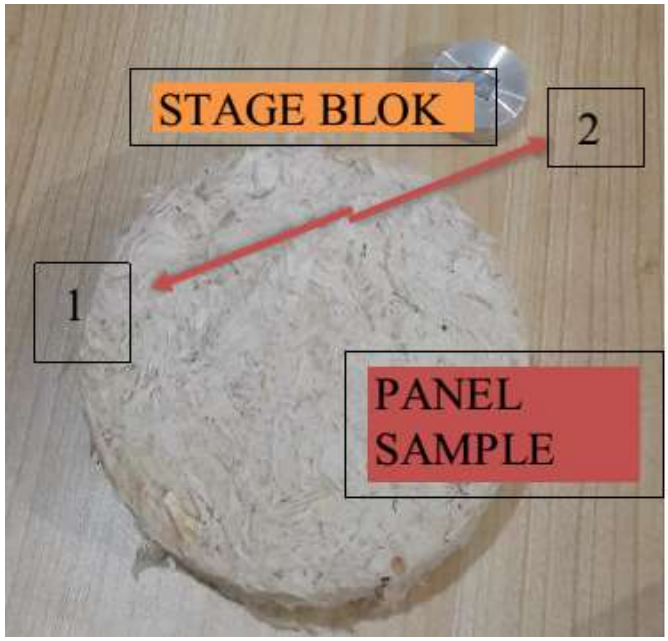

Figure 1. Sample test panel with 2 sample test points and test block stage

Second, Prepare equipment, especially those found in an electron microscope or SEM, including: An electron gun, generally in the form of a filament made from an element that easily releases electrons, for example tungsten; Lenses for electrons, in the form of lenses, are magnetic because negatively charged electrons can be deflected by a magnetic field; Vacuum system, because electrons are very small and light, if there are other air molecules the electrons traveling towards the target will be scattered by the collision before hitting the target so that they disappear (Cañavate et al., 2016; Wijayanto et al., 2013; Zhou et al., 2014).

The testing in this research aims to determine the chemical composition of chicken feather panel specimens which will later be used as a new alternative material in the field of architecture. The measurement method uses several stages:

- Determine the chicken feather panel sample preparation area point as shown in Figure 1.
- Prepare 2 carbon tip block stages because there are 2 measurement concentration points.
- Carry out the sample preparation process starting from point no. 1 to point no. 2.

- Attach the chicken feather panel samples from point no. 1 and point no. 2, to each stage block that has been attached with a Carbon tip using an iron spatula.
- Put each sample that has been attached to the Carbon tip block stage into a preparation box that has been labeled according to the number of points.
- Insert the preparation box containing the sample into the testing room.
- Before the sample is tested) a coating process (gold plating) is first carried out using the Smart Coater tool on the sample or material one by one for ± 1 minute.
- The next step is to insert the carbon tip block stage that has been coated into the stage holder.

After the coating process is complete and the sample has been inserted into the stage holder, the chicken feather panel sample is ready to determine its morphology.

Result and Discussion

Chicken Feather Panel Density Analysis

The process of making chicken feather panels using a biocomposite containing a higher content of chicken feathers, making it possible to produce low feathers due to the feather's light, thin and elastic character, from previous research the density of chicken feather panels was found to be 0.38-0.40 g/cm³ (Ansarullah & Mukhtar, 2022), and includes a type of rigid type soft fiber board, RF (rigid), 0.15-0.40 g/cm³, and based on ASTM 1974 is categorized as Low Density Particle Board in standard designation 1554 -67, classifying. Low density particle board is particle board that has a density of less than 37 lb/ft³ or a specific gravity of less than 0.59 g/cm³ [15]. Therefore, the inclusion of chicken feathers in a thermoplastic matrix has the potential to lower the density of biocomposites more than other reinforcing natural fibers (Poly, 2018).

Table 1. Description of Energy (EC), (to V), Mass, Atoms and Moles, Chicken Feather Panel Sample at Point.

No	Element	EC Minimum Emission Voltage (to V)	Dough %	Atom %	Mol %	compound
1	B K	0.183	22.17	47.65	40.06	B2O3
2	C K	0.277	1.86	3.59	6.04	C
3	N K	0.392	1.28	2.12	3.56	N
4	O K	0.525	10.67	15.49	-	-
5	Mg K	1.253	0.62	0.59	0.99	MgO
6	Al K	1.486	0.56	0.48	0.41	Al2O3
7	Si K	1.739	4.48	3.70	6.23	SiO2
8	S K	2.307	1.55	1.12	1.89	SO3
9	Ca K	3.690	35.49	20.57	34.59	CaO
10	Sc K	4.088	0.59	0.31	0.26	Sc2O3
11	Ge L	1.188	0.63	0.20	0.34	GeO2
12	As L	1.282	1.23	0.38	0.32	As2O3
13	Se L	1.379	0.83	0.24	0.41	SeO2
14	Br L	1.480	3.35	0.97	1.64	Br
15	Rb L	1.694	1.49	0.40	0.34	Rb2O
16	Ru L	2.558	0.60	0.14	0.23	RuO2
17	Sb L	3.604	2.11	0.40	0.34	Sb2O3
18	Te L	3.769	3.73	0.68	1.14	TeO2
19	I L	3.937	2.09	0.38	0.32	I2O5
20	W M	1.774	2.30	0.29	0.49	WO3
21	Os M	1.914	0.95	0.12	0.20	OsO4
22	Ir M	1.977	0.53	0.06	0.05	Ir2O3
23	Pb M	2.342	0.90	0.10	0.17	PbO
TOTAL		44.838	100	100	100	

SEM (Scanning Electron Microscope) Test Results

Optical microscope and SEM (Scanning Electron Microscope) tests were used to obtain images of the microstructure of the specimen. Following are the SEM test results which will be displayed as follows:

a) Discussion of Point Feather Panel Sample 1

Based on data from the analysis of Energy Dispersive the highest are elements B (Boron), C (Carbon), S (Sulphur) and Ca (Calcium). For element B (Boron) with a mass percentage value of %; 55.24%, Atomic percentage %; 75.06%, and percentage Mole %; 66.38% which is compounded with oxygen (B2O3) with a Minimum Emission Voltage (EC) of 0.183 keV, Meanwhile for element C (Carbon) it has a Mass percentage value of %; 6.71%, Atomic percentage %; 8.21%, and Mole percentage %; 14.52% with a Minimum Emission Voltage (EC) of 0.277 keV, while for the

element S (Sulfur) with a Mass percentage value of %; 11.47%, Atomic percentage %; 5.25%, and Mole percentage %; 9.30% which is compounded with oxygen (SO3) with a Minimum Emission Voltage (EC) of 2,307 keV, and for the Ca (Calcium) element it has a Mass percentage value of %; 7.11%, Atomic percentage %; 2.61%, and Mole percentage %; 4.61% which is a compound with oxygen (CaO) with a Minimum Emission Voltage (EC) of 3,690 keV, each of which is in the electron shell letter (K).

Based on the data from the analysis of Energy Dispersive 3,690 keV while the lowest Minimum Emission Voltage (EC) is element B (Boron) which is in the electron shell letter (K) of 0.183 keV with a total minimum emission voltage (Ec) of 20,828 keV. To make it easier to see the comparison of the values (EC) of the Minimum Emission Voltage (keV) of the Chicken Feather Panel Sample point No.3 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 2.

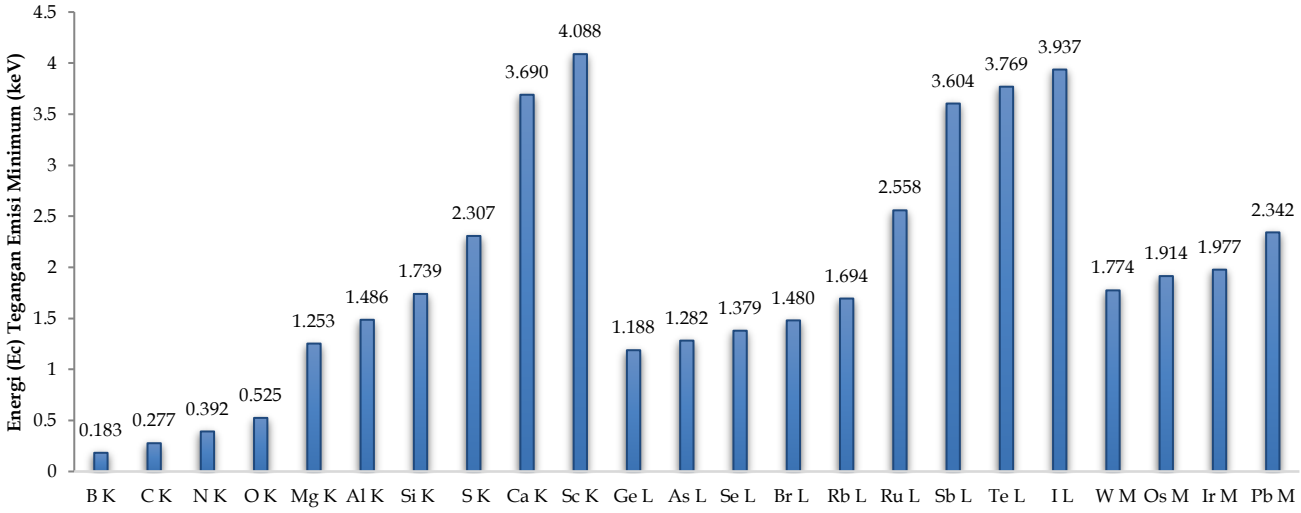

Figure 2. Relationship between Element and Energy (EC) Minimum Emission Voltage (keV)

Based on the data from the analysis of Energy Dispersive 10.67%, and the element Ca (Calcium) at 35.49%, each of which is in the electron shell letter (K), while the lowest mass percentage (%) is the element Ir (Iridium) at 0.53% which is in the electron shell letter (M). To make it easier to see the comparison of the Mass percentage values % Elements of Chicken Feather Panel Sample point No. 1 obtained from the results of the EDS analysis that has been carried out, can be presented in figure 3.

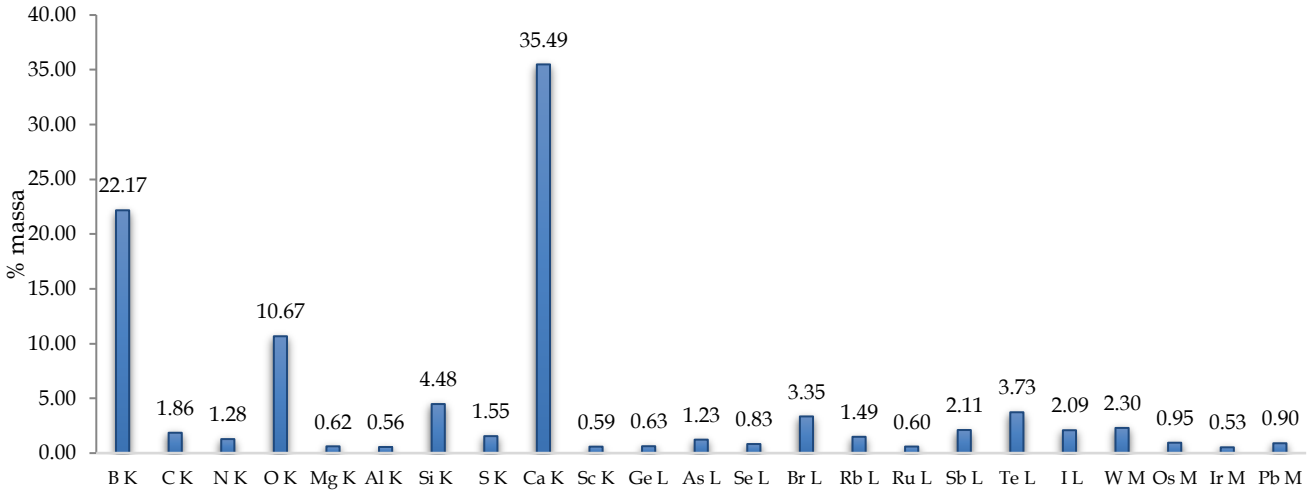

Figure 3. Relationship between elements and mass

Based on the data from the analysis of Energy Dispersive, and the element Ca (Calcium) of 20.57%, each of which is in the electron shell letter (K). Meanwhile, the lowest atomic percentage is the element Ir (Iridium) at 0.06% which is in the electron shell letter (M).

To make it easier to see the comparison of the Atom % Element (Element) percentage values for the Chicken Feather Panel Sample point No. 1 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 4.

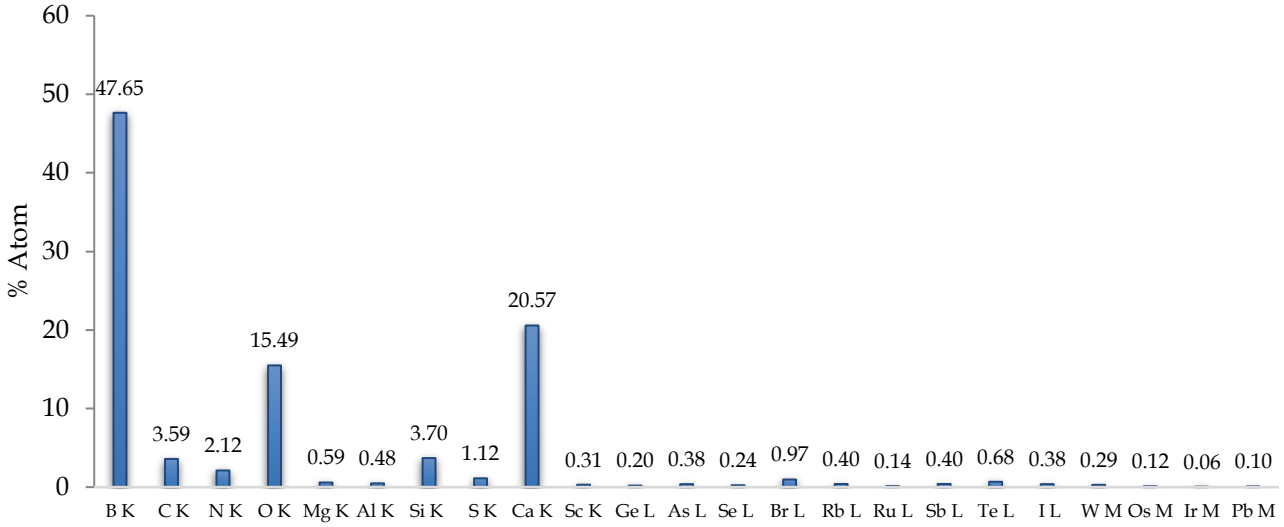

Figure 4. Relationship between elements and atoms

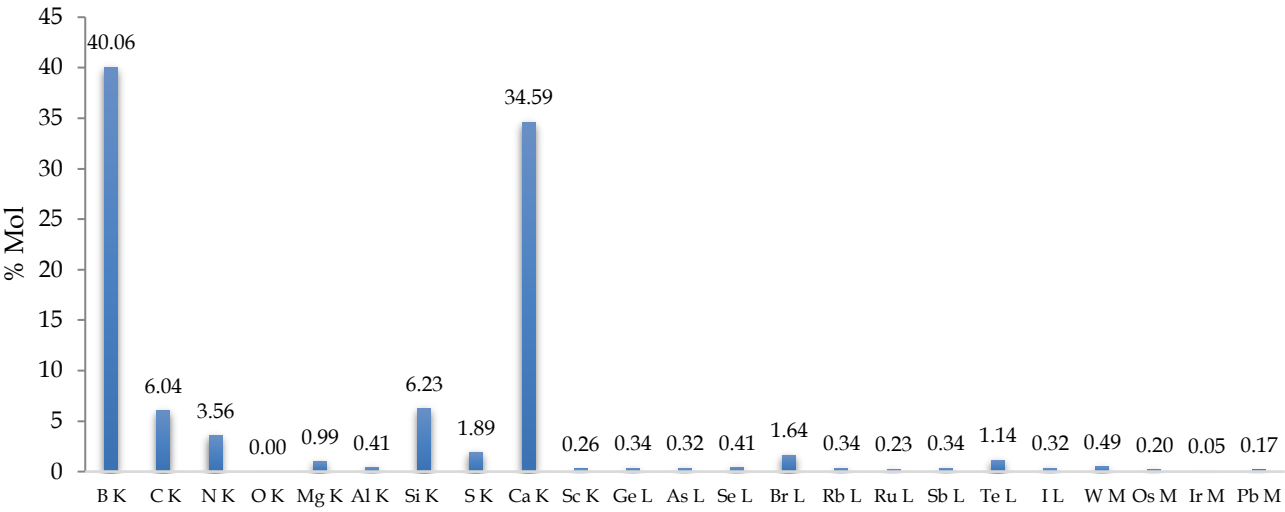

Figure 5. Relationship between elements and moles (%)

Based on data from the analysis of Energy Dispersive each of which is in the electron shell letter (K). While the Mole percentage. The lowest % is the element Ir (Iridium) of 0.05% which is in the electron shell letter (M).

To make it easier to see the comparison of the Mole % Element (Element) percentage values for Chicken Feather Panel Sample point No. 1 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 6

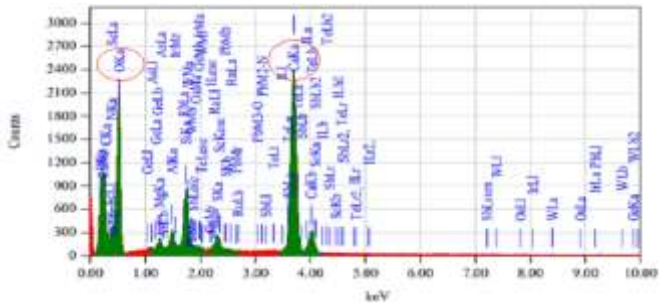

Figure 6. Qualitative Data of Point 1 test panel samplesased on the results of Energy Dispersive X- analysis

Discussion of Qualitative Data for Chicken Feather Panel Sample Point No. 1

Ray Spectroscopy (EDS) on the PBA sampleat point No.2, qualitative data, the dominant high element from the count spectrum designation above is element C (Carbon) and element O (Oxygen) which are in the Minimum Emission Voltage (EC) range between 0.00–4.00 keV. Qualitative data indicating the spectrum was taken with a magnitude image of 1,000 X with a particle morphology size of 30 µm at acceleration voltage 15 kV as seen in the photo image below.

Table 2. Description of Energy (EC), (keV), Mass, Atoms and Moles, Chicken Feather Panel Sample at Point No.2

No	Element	EC Minimum Emission Voltage (to V)	Dough %	Atom %	Mol %	compound
1	B K	0.183	55.24	75.06	66.38	B2O3
2	C K	0.277	6.71	8.21	14.52	C
3	N K	0.392	2.02	2.12	3.74	N
4	O K	0.525	5.96	5.47	-	-
5	Al K	1.486	0.59	0.32	0.29	Al2O3
6	S K	2.307	11.47	5.25	9.30	SO3
7	Ca K	3.690	7.11	2.61	4.61	CaO
8	Rb L	1.694	1.67	0.29	0.25	Rb2O
9	W M	1.774	1.23	0.10	0.17	WO3
10	Os M	1.914	0.92	0.07	0.13	OsO4
11	Ir M	1.977	0.37	0.03	0.02	Ir2O3
12	Tl M	2.267	4.09	0.29	0.26	Tl2O3
13	Pb M	2.342	2.62	0.19	0.33	PbO
TOTAL		20.828	100	100	100	

b) Discussion of Point Feather Panel Sample 2

Based on data from the analysis of Energy Dispersive The highest are elements B (Boron), C (Carbon), S (Sulphur) and Ca (Calcium). For element B (Boron) with a mass percentage value of %; 55.24%, Atomic percentage %; 75.06%, and percentage Mole %; 66.38% which is compounded with oxygen (B2O3) with a Minimum Emission Voltage (EC) of 0.183 keV, Meanwhile for element C (Carbon) it has a Mass percentage value of %; 6.71%, Atomic percentage %; 8.21%, and Mole percentage % ; 14.52% with a Minimum Emission Voltage (EC) of 0.277 keV, while for the element S (Sulfur) with a Mass percentage value of %; 11.47%, Atomic percentage %; 5.25%, and Mole percentage %; 9.30% which is compounded with oxygen (SO3) with a Minimum Emission Voltage (EC) of 2,307 keV, and for the Ca (Calcium) element it has a Mass percentage value of %; 7.11%, Atomic percentage %; 2.61%, and Mole percentage %; 4.61% which is a compound with oxygen (CaO) with a Minimum Emission Voltage (EC) of 3,690 keV, each of which is in the electron shell letter (K).

Based on the data from the analysis of Energy Dispersive 3,690 keV while the lowest Minimum Emission Voltage (EC) is element B (Boron) which is in the electron shell letter (K) of 0.183 keV with a total minimum emission voltage (Ec) of 20,828 keV. To make it easier to see the comparison of the values (EC) of the Minimum Emission Voltage (keV) of the Chicken Feather Panel Sample point No.3 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 7.

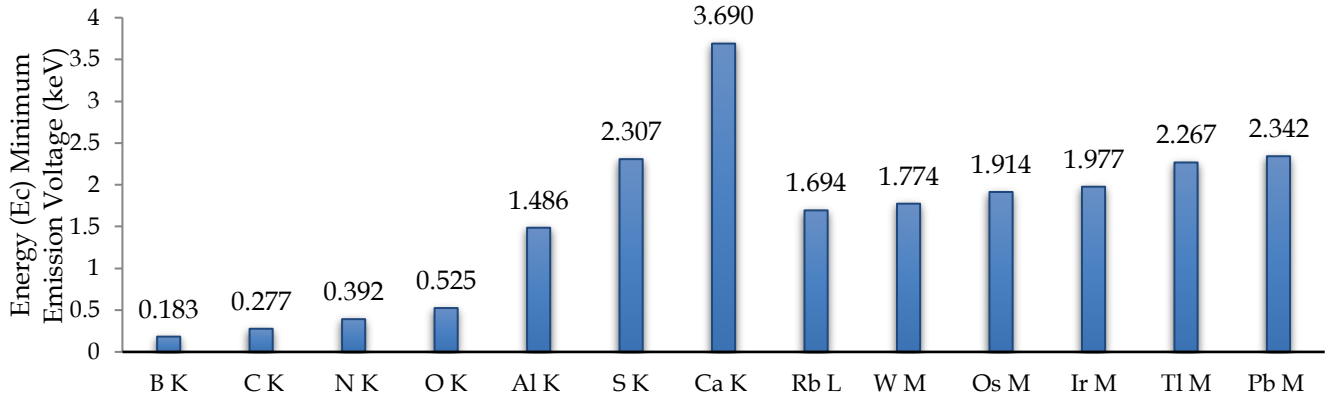

Figure 7. Relationship between Element and Energy (EC) Minimum Emission Voltage (keV)

Based on the data from the analysis of Energy Dispersive 11.47%, each of which is in the electron shell letter (K), while the lowest mass percentage (%) is the element Ir (Iridium) at 0.37% which is in the electron shell letter (M). To make it easier to see the comparison of the Mass percentage values % Elements of Chicken Feather Panel Sample point No. 3 obtained from the results of the EDS analysis that has been carried out, can be presented in figure 8.

Based on the data from the analysis of Energy Dispersive each of which is in the electron shell letter (K). While the atomic percentage. The lowest % is the element Ir (Iridium) at 0.03% which is in the electron shell letter (M). To make it easier to see the comparison of the Atom % Element (Element) percentage values for the Chicken Feather Panel Sample point No. 2 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 9.

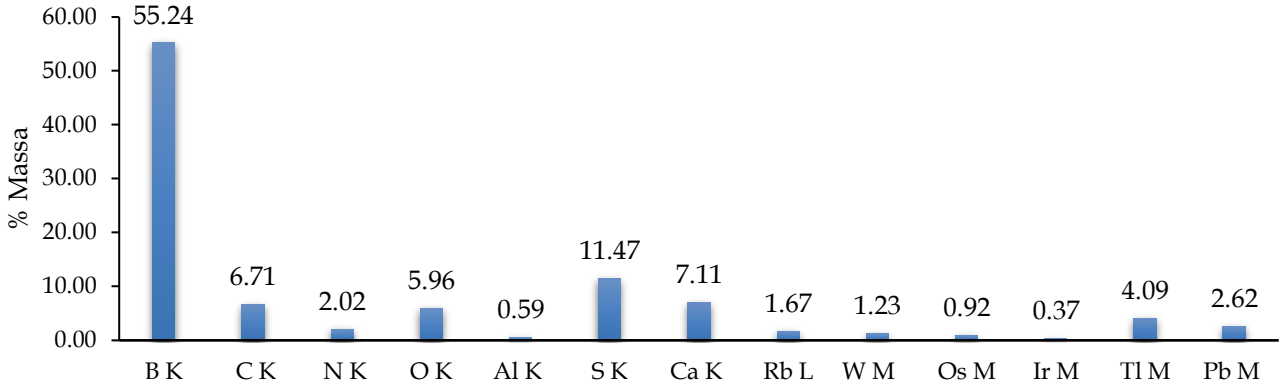

Figure 8. Relationship between elements and mass (%)

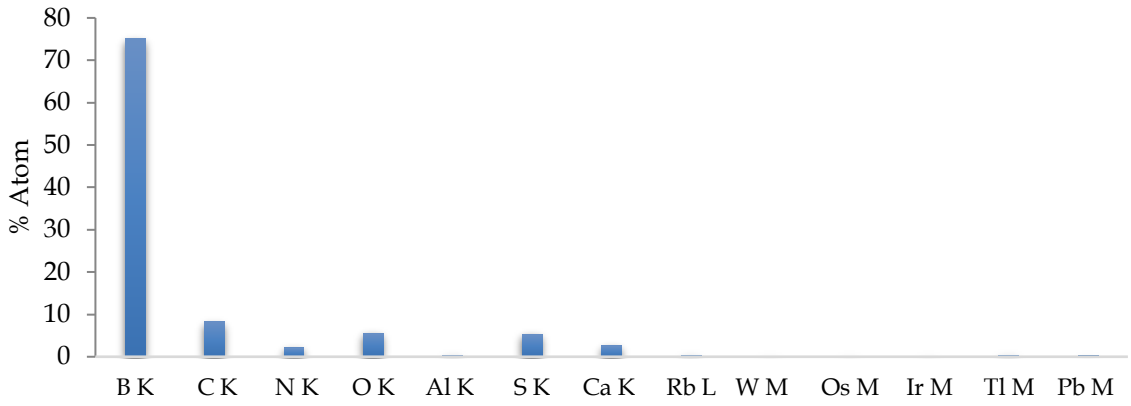

Figure 9. Relationship between elements and atoms (%)

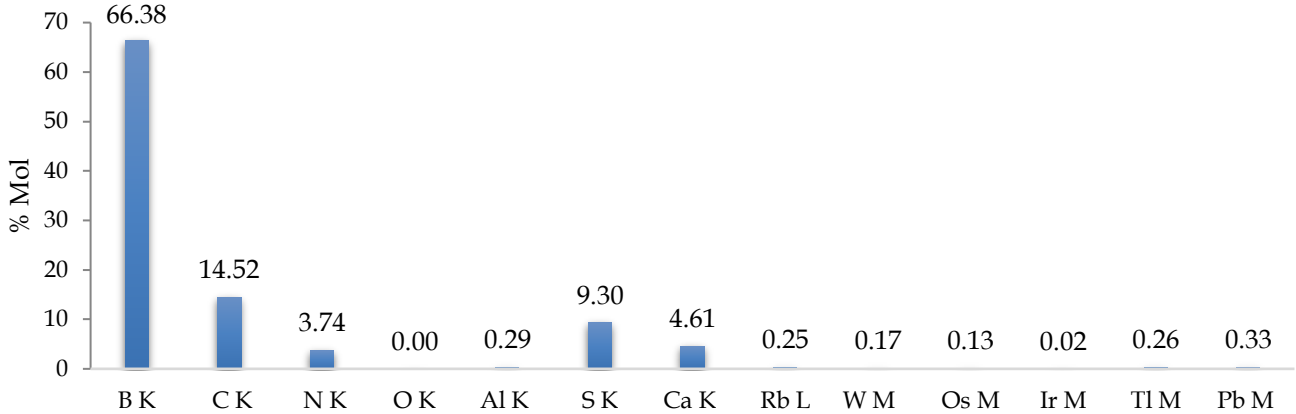

Figure 10. Relationship between elements and moles (%)

Based on data from Energy Dispersive X-Ray Spectroscopy (EDS) analysis of Chicken Feather Panel Samples point no. 3 in Table 2 above shows that the highest mol% percentage is element B (Boron) at 66.38%, element C (Carbon) at 14.52%, and element S (Sulphur) at 9.30% which each is in the electron shell letter (K). Meanwhile, the lowest mol% percentage is the element Ir (Iridium) at 0.02% which is in the electron shell letter (M). To make it easier to see the comparison of the Mole % Element (Element) percentage values for the Chicken Feather Panel Sample point No. 2 obtained from the results of the EDS analysis that has been carried out, it can be presented in figure 10.

Discussion of Qualitative Data for Chicken Feather Panel Samples Point No.2

Ray Spectroscopy (EDS) on the PBA sample at point No. 3. The dominant high qualitative data element from the count spectrum designation above is the elements C (Carbon) and B (Boron) which are in the Minimum Emission Voltage (EC) range between 0.00 – 4.00 keV. Qualitative data indicating the spectrum was taken with a magnitude image of 1,000X with a particle morphology size of 30 µm at an acceleration voltage of 15 kV as seen in the figure 12.

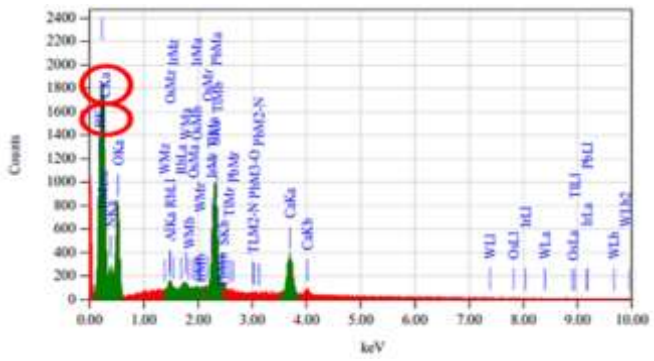

Figure 11. Qualitative data for point 2 test panel samples based on the results of Energy Dispersive X- analysis

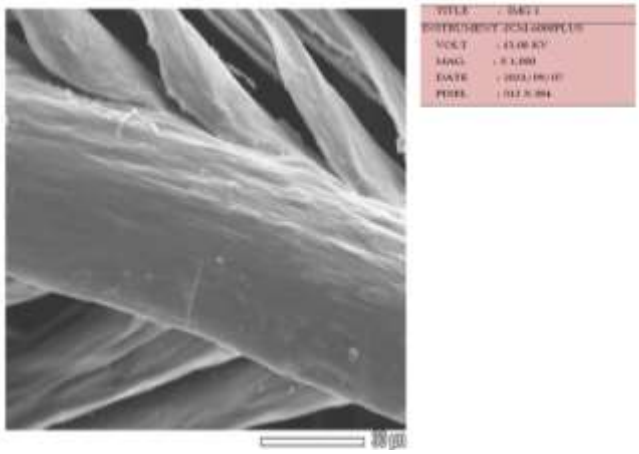

Figure 12. Point 2 test panel sample spectrum (acceleration voltage 15 kV)

Conclusion

From the results of qualitative data analysis of EDS detection using the JEOL tool on Chicken Feather Panel samples at points No. others that are detected automatically via EDS test equipment which is in the Minimum Emission Voltage (EC) range between 0.00 – 4.00 keV. From the results of quantitative data analysis of EDS detection using the JEOL tool on the Chicken Feather Panel sample at point No. 1, it shows that the highest Mass % percentages are elements B (Boron), O (Oxygen), and Ca (Calcium) respectively amounted to 22.17%, 10.67%, and 35.49%, while the highest Atom% percentages were elements B (Boron), O (Oxygen), and Ca (Calcium) respectively at 47.65%, 15.49%, and 20.57%, and The highest mol% percentages are elements B (Boron) and Ca (Calcium) at 40.06% and 34.59% respectively. From the results of quantitative data analysis of EDS detection using the JEOL tool on the Chicken Feather Panel sample at point No. 2, it shows that the highest Mass % percentages are element B (Boron) and element S (Sulphur) at 55.24% and 11.47% respectively. %, while the highest Atom% percentages are element B (Boron) and element C (Carbon) at 75.06% and 8.21% respectively, and the highest Mol% percentages are element B (Boron), element C (Carbon), and the element S (Sulphur) respectively 66.38% , 14.52% , and 9.30%. After observing the topographic structure of the chicken feather panel using SEM to see the characteristics of the panel in detail from the formation side by referring to the Lifecycle Assessment (LCA) standard in Indonesia, the researcher has carried out an assessment, and found that the chicken feather panel material met the criteria as an environmentally friendly and sustainable material.

Acknowledgments

Researchers would like to thank the Ministry of Education, Culture, Research and Technology. The Directorate General of Higher Education, Research and Technology provided funding for this research through the Research and Community Service.

Author Contribution

Conceptualization, Ansarullah Faharuddin; methodology, Mukhthar Thahir Syarkawi; software, Juhana Said; validation, Muhammad Zainal Altim; formal analysis, investigation, data curation; Zulkarnain Hamson; data curation, Siti Aisah; original draft preparation writing, Zulkarnain Hamson; review writing and editing, Muhammad Zainal Altim, Zulkarnain Hamson and Siti Aisah; visualization, Zulkarnain Hamson; supervision, Ansarullah Faharuddin and Zulkarnain Hamson; project administration, Ansarullah Faharuddin and Mukhthar Thahir Syarkawi.

Funding
This research was funded by the Ministry of Education, Culture, Research and Technology in the context of carrying out research activities.

Conflict of Interest
The authors declare no potential conflict of interest.

References

Aranberri, I., Montes, S., Azcune, I., Rekondo, A., & Grande, H.-J. (2017). Fully Biodegradable Biocomposites with High Chicken Feather Content. *Polymers*, *9*(11), 593. https://doi.org/10.3390/polym9110593

Aranberri, I., Montes, S., Azcune, I., Rekondo, A., & Grande, H.-J. (2018). Flexible Biocomposites with Enhanced Interfacial Compatibility Based on Keratin Fibers and Sulfur-Containing Poly(urea-urethane)s. *Polymers*, *10*(10), 1056. https://doi.org/10.3390/polym10101056

Azcune, I., & Odriozola, I. (2016). Aromatic disulfide crosslinks in polymer systems: Self-healing, reprocessability, recyclability and more. *European Polymer Journal*, *84*, 147–160. https://doi.org/10.1016/j.eurpolymj.2016.09.023

Barone, J. R., & Schmidt, W. F. (2005). Polyethylene reinforced with keratin fibers obtained from chicken feathers. *Composites Science and Technology*, *65*(2), 173–181. https://doi.org/10.1016/j.compscitech.2004.06.011

Bessa, J., Souza, J., Lopes, J. B., Sampaio, J., Mota, C., Cunha, F., & Fangueiro, R. (2017). Characterization of thermal and acoustic insulation of chicken feather reinforced composites. *Procedia Engineering*, *200*, 472–479. https://doi.org/10.1016/j.proeng.2017.07.066

Cañavate, J., Aymerich, J., Garrido, N., Colom, X., Macanás, J., Molins, G., Álvarez, M., & Carrillo, F. (2016). Properties and optimal manufacturing conditions of chicken feathers/poly(lactic acid) biocomposites. *Journal of Composite Materials*, *50*(12), 1671–1683. https://doi.org/10.1177/0021998315595534

Cheong, C. W., Lee, Y. S., Ahmad, S. A., Ooi, P. T., & Phang, L. Y. (2018). Chicken feather valorization by thermal alkaline pretreatment followed by enzymatic hydrolysis for protein-rich hydrolysate production. *Waste Management*, *79*, 658–666. https://doi.org/10.1016/j.wasman.2018.08.029

Conzatti, L., Giunco, F., Stagnaro, P., Patrucco, A., Marano, C., Rink, M., & Marsano, E. (2013). Composites based on polypropylene and short wool fibres. *Composites Part A: Applied Science and Manufacturing*, *47*, 165–171. https://doi.org/10.1016/j.compositesa.2013.01.002

Cruz, S. M., & Viana, J. C. (2015). Melt blending and characterization of carbon nanoparticles-filled thermoplastic polyurethane elastomers. *Journal of Elastomers & Plastics*, *47*(7), 647–665. https://doi.org/10.1177/0095244314534097

Erlita, D., Puspitasari, A., & Isbandi, T. (2016). Reduksi Limbah Rumah Potong Ayam (Rpa) Sebagai Alternatif Bahan Ransum Pakan Berprotein. *Prosiding SNST Ke-7*, *1*(1), 1–4. Retrieved from https://publikasiilmiah.unwahas.ac.id/index.php/PROSIDING_SNST_FT/article/view/1463/1547

Gokce, O., Kasap, M., Akpinar, G., & Ozkoc, G. (2017). Preparation, characterization, and in vitro evaluation of chicken feather fiber–thermoplastic polyurethane composites. *Journal of Applied Polymer Science*, *134*(45), 45338. https://doi.org/10.1002/app.45338

Hafez, R. D. A., Hadzima-Nyarko, M., Ahmed, S. M., & Tayeh, B. A. (2023). Recycled Chicken Feather Sand as a Partial Replacement for Natural Sand for Producing Eco-Friendly Mortar. *Buildings*, *13*(2), 421. https://doi.org/10.3390/buildings13020421

Mihăilă, E.-G., Faraon, V. A., Deşliu-Avram, M., Neamțu, C., Constantinescu-Aruxandei, D., & Oancea, F. (2020). New Controlled-Release Fertilizers with Keratin-Based Coating from Chicken Waste Feathers. *The 16th International Symposium "Priorities of Chemistry for a Sustainable Development" PRIOCHEM*, *57*(1), 20. https://doi.org/10.3390/proceedings2020057020

Rekondo, A., Martin, R., Ruiz de Luzuriaga, A., Cabañero, G., Grande, H. J., & Odriozola, I. (2014). Catalyst-free room-temperature self-healing elastomers based on aromatic disulfide metathesis. *Mater. Horiz.*, *1*(2), 237–240. https://doi.org/10.1039/C3MH00061C

Sari, E. P. (2015). Pemanfaatan limbah bulu ayam sebagai pakan ternak ruminansia. *Pros. Sem. Nas. Masy. Biodiv. Indon*, *1*(1), 136–138,. https://doi.org/10.13057/psnmbi/m010123

Sumardiono, S., Jos, B., Dewanti, A. A. E., Mahendra, I., & Cahyono, H. (2021). Biogas Production from Coffee Pulp and Chicken Feathers Using Liquid- and Solid-State Anaerobic Digestions. *Energies*, *14*(15), 4664. https://doi.org/10.3390/en14154664

Thyagarajan, D., Barathi, M., & Sakthivadivu, R. (2013). Scope of Poultry Waste Utilization. *IOSR Journal of Agriculture and Veterinary Science*, *6*(5), 29–35. https://doi.org/10.9790/2380-0652935

Ulupi, N., Nuraini, H., Parulian, J., & Kusuma, S. Q.

(2018). Karakteristik Karkas dan Non Karkas Ayam Broiler Jantan dan Betina pada Umur Pemotongan 30 Hari. *Jurnal Ilmu Produksi Dan Teknologi Hasil Peternakan*, *6*(1), 1–5. https://doi.org/10.29244/jipthp.6.1.1-5

Wijayanto, S. O., & A.P Bayuseno. (2013). Analisis Kegagalan Material Pipa Ferrule Nickel Alloy N06025 Pada Waste Heat Boiler Akibat Suhu Tinggi Berdasarkan Pengujian : Mikrografi Dan Kekerasan. *Jurnal Teknik Mesin Undip*, *1*(4), 33–39. Retrieved from https://ejournal3.undip.ac.id/index.php/jtm/article/view/6466

Zhou, L.-T., Yang, G., Yang, X.-X., Cao, Z.-J., & Zhou, M.-H. (2014). Preparation of regenerated keratin sponge from waste feathers by a simple method and its potential use for oil adsorption. *Environmental Science and Pollution Research*, *21*(8), 5730–5736. https://doi.org/10.1007/s11356-014-2513-8