International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2024 | Issue 60 | Volume 16 | Number 3 | Pages 36-40

EFFECT OF OIL USE ON AGGLOMERATION PROCESS FOR COAL QUALITY IMPROVEMENT

N. Jafar [1] M.I. Juradi [1] S. Bakri [1] Lamatinulu [2]

1. Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, nurliah.jafar@umi.ac.id, muhidris.juradi@umi.ac.id, suriyanto.bakri@umi.ac.id,
2. Department of Industrial Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, lamatinulu@gmail.com

Abstract- Parameters for determining coal quality can be seen from the ash value (A), sulfur (S), and heating value (CV). The presence of ash (A) and sulfur (S) in coal (C) is highly undesirable, whereas the high calorific value (CV) of coal (C) is desirable. One effort that can be made to reduce ash (A) and sulfur (S) and increase the heating value (CV) is the agglomeration method (AM). This research aims to determine the effect of variations in oil volume and compare the use of palm cooking oil (CPO) and pure coconut oil (VCO) on reducing ash (A), sulfur (S) and increasing the calorific value (CV) of coal (C). The research method used is an experimental method and a quantitative method by collecting several fixed variables and independent variables and then the data is interpreted to find the best conditions for each experimental result. The research results showed a decrease in ash (A) and sulfur (S) levels as well as an increase in the calorific value (CV) in 10 mL of fried palm oil (CPO), namely 32.73%, 29.50% and 20.67%. The reduction in ash (A), sulfur (S), and calorific value (CV) in 15 mL of palm cooking oil (CPO) was 37.80%, 39.57%, and 28.02%, respectively. The reduction in ash (A), sulfur (S), and calorific value in 20 mL of palm cooking oil (CPO) was 57.65%, 53.24%, and 40.46%. The reduction in ash content (A), sulfur (S), and calorific value in 20 mL of pure coconut oil (VCO) was 73.39%, 35.61%, and 38.08%. From the research results it can be concluded that the agglomeration method (AM) of water and oil can reduce ash (A) and sulfur (S) and increase the calorific value (CV).

Keywords: Coal, Agglomeration, Ash, Sulfur, Calorific Value.

1. INTRODUCTION

Data from the Director General of Mineral and Coal of the Ministry of Energy and Mineral Resources indicate that Indonesia has a very large potential for coal resources., Indonesia's coal reserves currently reach 38.84 billion tones with an average coal production of 600 million tons per year, so the age of coal reserves is still 65 years if it is assumed that there are no new reserve findings [1]. Until now, coal is still the foundation in the Asia Pacific region in providing affordable and cheap energy. In line with measures to reduce greenhouse gas emissions from the energy sector, the Ministry of Energy and Mineral Resources is seeking new breakthroughs through the use of clean energy-based technology, which is expected to optimize coal utilization in Indonesia [2].

Beyond calorific value, ash (A) and Sulphur (S) are contaminants and a measure of coal quality. Burning coal will produce Sulphur (S) oxides due to its Sulphur (S) concentration [3]. This substance may react with atmospheric water vapor to produce H_2SO_3 and H_2SO_4. Acid rain will happen if both acids are polluted in the atmosphere and descend with rains at the same time. Sulphur (S) oxides released from burning coal have the potential to produce acid rain hundreds of miles away. Efforts to reduce ash (A) and sulfur (S) content in coal, in addition to removing impurities, are also an effort to increase the calorific value of coal so that it can provide added value for improving coal quality [4]. Washing the coal reduces the amount of ash (A) and Sulphur (S) from inorganic components; this process is known as the agglomeration technique [5]. The presence of sulfur will also affect the compounds present in coal so that it is necessary to reduce the sulfur content [6].

Ash (A) and Sulphur (S) may be effectively removed from coal using the oil-water agglomeration method. Oil agglomeration can be used to create a solid, viscous product by combining coal particles of various sizes, or agglomerates [7]. Because the coal surface is hydrophobic (hates water) and lipophilic (loves oil), this agglomeration approach can be used [8]. Waste material is submerged in the media, but clean coal floats in the same medium (water) [9]. Coal particles may be formed into agglomerates to create coal oil mixes since they are hydrophobic by nature [10]. However, the hydrophilic mineral particles that give coal its ash (A) and Sulphur (S) are unaffected and stay in the water [11]. The coal agglomeration particles may be separated from the mineral particles because they are bigger. When oil is present during washing, water containing ash (A) will no longer stick to the coal surface [12].

Registered: 240127 Article Info: 1826 Accepted: 240823
Reserved: 240414 Available: 240930

This study is to examine the use of virgin coconut oil and palm cooking oil on lowering ash (A), Sulphur (S), and raising the calorific value (CV) of coal, as well as to ascertain the impact of oil volume variation.

2. MATERIAL AND METHOD

2.1. Coal Samples

The coal samples used came from Lanne village, Tondong Tallasa sub-district, Pangkep district, South Sulawesi. The agglomeration process stage is carried out after the coal samples obtained are prepared using a double roll crusher and ball mill and then sifted using a sieve shaker to get the required particle size of –200 +325 mesh (–74 + 44 μm).

2.2. Experiment Procedure

The agglomeration process begins with the preparation of tools and materials, then put water first into a 250 mL Erlenmeyer flask with a volume that adjusts to the volume of oil used to stay at a volume of 150 mL, into the Erlenmeyer flask along with coal measuring –200 + 325 mesh (–74 + 44 μm) as much as ±15 grams. The Erlenmeyer flask that has been filled with coal and water is then stirred with a stirrer at 1,000 rpm for 3 minutes, after which the initial stirring between coal and water is carried out by entering 10 mL of oil and stirring again for 3 minutes. After 3 minutes of stirring between coal, water and oil, the agglomerates formed were then allowed to stand for 3 minutes and then the agglomerates were filtered with a 200-mesh sieve so that the water would drip down for 24. The resulting agglomerate is then ovenised at 110 °C for 2 hours.

The heated agglomerates are then ready for proximate, total sulfur (S) and calorific value analyses to compare with the data before the agglomeration process. Subsequent experiments with oil volumes of 15 mL and 20 mL were conducted with the same process. The most optimal results from these three oils will then be used for the experiment on virgin coconut oil.

2.3. Analytical Measurement

Samples that have gone through the drying process are then analyzed proximate to know inherent moisture standard method ASTM D3173/D3173M [13], volatile matter standard method ASTM D3175 [14], fixed carbon standard method ASTM D5142 [15], ash content with standard method used ASTM D3174 [16], total sulfur analysis ASTM D2492 [17] and calorific value with standard measurement ASTM D2015 [18]. The results of the analysis will then be compared with the initial data before agglomeration in the form of a comparison graph made on Microsoft excel and also a scientific explanation of changes in data on ash content, sulfur and calorific value before and after the agglomeration process using the equation for reducing ash content (Equation 1) [16], the equation for reducing sulfur content (Equation 2) [17] and increasing calorific value (Equation 3) [18] can be calculated using the equation:

$$\text{Decrease in AC (\%)} = \frac{(a_1 - a_2)}{a_2} \times 100\% \quad (1)$$

$$\text{Decrease in S (\%)} = \frac{(s_1 - s_2)}{s_2} \times 100\% \quad (2)$$

$$\text{Increase in CV (\%)} = \frac{(c_1 - c_2)}{c_2} \times 100\% \quad (3)$$

Table 1. Description of Equations (1)-(3) [16, 17, 18]

No.	Description	Unit	Code
1	Ash content of coal samples	%	a_1
2	Coal ash content after agglomeration process	%	a_2
3	Total sulfur content of coal samples	%	s_1
4	Total sulfur content after agglomeration process	%	s_2
5	Calorific Value of coal samples	(cal/gr)	c_1
6	Calorific Value after agglomeration process	(cal/gr)	c_2

3. RESULTS AND DISCUSSION

3.1. Coal Samples Characteristics

Analysis of the characteristics of coal samples reveals the value of inherent moisture (IM) of 10.50%, volatile matter (VM) by 40.21% fixed carbon (FC) at 12.57%, ash (A) content (AC) of 36.72%, total sulfur (S) (TS) by 2.78% and The Calorific Value (CV) of 3,648 cal/gr. Table 2 displays the full coal analysis results.

Table 2. Coal quality based on proximate and calorific value analyses

No.	Parameters	Analysis Result
1	Inherent Moisture (IM)	10.50% adb
2	Volatile Matter (VM)	40.21% adb
3	Fixed Carbon (FC)	12.57% adb
4	Ash Content (AC)	36.72% adb
5	Total Sulfur (S)	2.78% adb
6	Calorific Value (CV)	3,648 cal/gr

3.2. Water and Oil Agglomeration Results

In conducting the research, 2 types of oil were used, namely Cooking Palm Oil (CPO) and Virgin Coconut Oil (VCO), which will be used as a comparison at the end. In this study, proximate analysis, total sulfur (S) and calorific value (CV) of coal samples were used. The results of coal sample analysis after and before agglomeration can be seen in Table 3.

Table 1 shows the value of the coal sample before the agglomeration process. The focus of this research is with initial data of ash (A) content of 36.72%, total sulfur (S) of 2.78% and calorific value (CV) of 3,648 cal/gr. Table 3 above also shows a decrease in ash (A), sulfur (S) and an increase in calorific value (CV) in each experiment. The highest decrease in ash (A) content occurred in coal agglomeration with 20 mL virgin coconut oil (VCO), namely 73.39%, the highest decrease in sulfur (S) content occurred in coal agglomeration with 20 mL Cooking Palm Oil (CPO), namely 53.24% and the highest increase in calorific value (CV) occurred in agglomeration with 20 mL cooking palm oil, namely 40.46%.

Table 3. Analytical results of coal samples before and after agglomeration process

Sample ID	Parameters					
	Proximate (%adb)		S (%adb)	Decrease in S (%)	CV (cal/gr)	Increase in CV (%)
	AC	Decrease in AC (%)				
Starting Coal	36.72		2.78		3,648	
CPO 10 mL	24.70	32.73	1.96	29.50	4,402	20.67
CPO 15 mL	22.84	37.80	1.68	39.57	4,670	28.02
CPO 20 mL	15.55	57.65	1.30	53.24	5,124	40.46
VCO 20 mL	9.77	73.39	1.79	35.61	5,037	38.08

3.3. Effect of The Addition of Palm Cooking Oil and Virgin Coconut Oil on Proximate Results

The effect of agglomeration on coal after the agglomeration process using Cooking Palm Oil (CPO) 10 mL, 15 mL, 20 mL and virgin coconut oil (VCO) 20 mL In Figure 1, the outcomes of the proximate analysis are displayed.

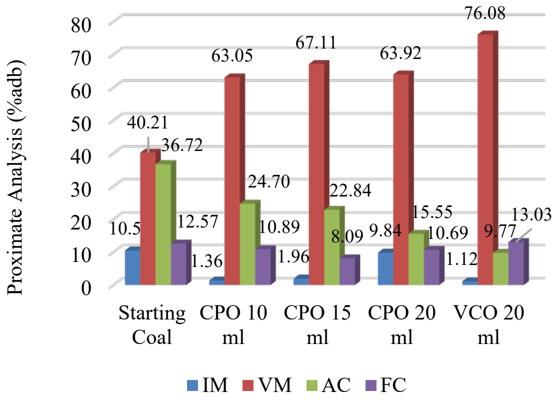

Figure 1. Comparison of proximate analysis after agglomeration process

Figure 1 shows the changes in proximate analysis before agglomeration and after adding Cooking Palm Oil 10 mL, 15 mL, 20 mL and virgin coconut oil 20 mL, namely the inherent moisture content dropped to 1.36%, 1.96%, 9.84% and 1.12%. Inherent moisture of palm cooking oil 20 mL experienced the least decrease among other oil variations in the range of ±1%, this can occur because the waiting time of coal after the oven process affects the ability of coal to reabsorb water content where the longer the waiting time, the higher the coal reabsorbs its water content [19] in this study the samples that had been in the oven were left first before being put into the sample bottle. In volatile matter, namely 63.05%, 67.11%, 63.92% and 76.08%, this increase is thought to occur due to the compounding of coal carbon with oil, forming hydrocarbon groups that are more easily decomposed after undergoing the agglomeration process [20].

Ash (A) content also decreased in palm cooking oil 10 mL, 15 mL, 20 mL and virgin coconut oil 20 mL, namely to 24.70%, 22.84%, 15.55% and 9.77%. Coal particles may be converted into agglomerates in the form of mixes with oil since they are hydrophobic by nature. However, ash (A) and Sulphur (S) content in coal come from hydrophilic mineral particles, which are unaffected and stay in the water. Since coal agglomerate particles are larger than mineral particles, they can be [21]. The fixed carbon value decreased by about 10.89% 10.89%, 8.09%, 10.69% the decrease in fixed carbon is not in line with the increase in calorific value and in virgin coconut oil increased by 13.03%.

3.4. Effect of Palm Cooking Oil and Virgin Coconut Oil Addition on Total Sulfur (S) Analysis Result

Figure 2 shows the changes in total sulfur (S) between before agglomeration with palm cooking oil 10 mL, 15 mL, 20 mL and virgin coconut oil 20 mL which decreased by 1.96%, 1.68% 1.30% and 1.79%. Coal particles may be converted into agglomerates in the form of mixes with oil since they are hydrophobic by nature. However, ash (A) and Sulphur (S) content in coal come from hydrophilic mineral particles, which are unaffected and stay in the water. Coal agglomerate particles may be isolated from mineral particles because they are bigger [22].

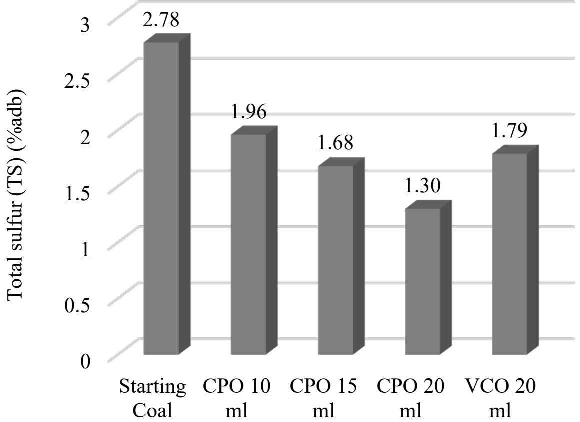

Figure 2. Comparison of total sulfur (S) after agglomeration process

3.5. Effect Of Palm Cooking Oil and Virgin Coconut Oil Addition on Coal Calorific Value

Figure 3 shows the changes in calorific value between before agglomeration with palm cooking oil 10 mL, 15 mL, 20 mL and virgin coconut oil 20 mL which increased to 4,402 cal/gr, 4,670 cal/gr, 5,124 cal/gr and 5,037 cal/gr. The percentage increase in calorific value was 20.67%, 28.02%, 40.46% and 38.08% respectively. Based on Figure 1. shows that the value of fixed carbon has decreased by about 10.89% 10.89%, 8.09% and 10.69% for palm oil has decreased fixed carbon on which is not in line with the increase in calorific value.

The decrease in carbon content caused by the agglomeration process does not cause the calorific value of coal to decrease, but instead increases. This shows that the calorific value of coal does not only depend on its carbon content, but still depends on other things, such as age, origin, environmental conditions of coal formation and so on [23].

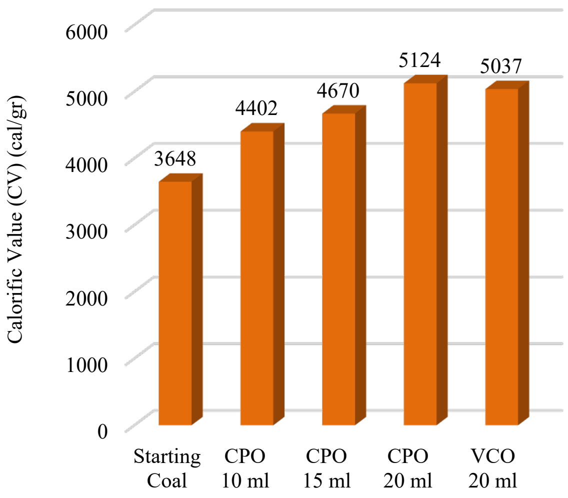

Figure 3. Calorific value (CV) comparison after agglomeration

4. CONCLUSIONS

The conclusion of this research is that the results of the agglomeration process with variable volume of Cooking Palm Oil (CPO) use obtained the best results at a volume of 20 mL with a decrease in ash (A) content by 57.65%, a decrease in sulfur (S) content by 53.24% and an increase in calorific value (CV) by 40.46%. While the results of the comparison of the use of Cooking Palm Oil (CPO) and virgin coconut oil (VCO) with the same volume of oil, namely 20 mL, a decrease in ash (A) content using virgin coconut oil (VCO) obtained the best results with a percentage decrease of 73.39%, on the other hand, a decrease in sulfur (S) content and an increase in calorific Values (CV), the best results were obtained by using cooking palm oil (CPO) with each value of 53% for a decrease in sulfur (S) content and 40.46% for an increase in calorific values (CV). It can be seen that the use of virgin coconut oil (VCO) in the agglomeration process is the optimum result obtained.

ACKNOWLEDGEMENTS

The faculty of industrial technology provided the authers with moral and financial support that allowed them to do this study and write an essay.

REFERENCES

[1] Ministry of Energy and Mineral Resources, "Indonesia's Mineral and Coal Policy", Directorate General of Min. and Coal, No. a, Jakarta, Indonesia, 2021.
[2] Ministry of Energy and Mineral Resources, "Road Map for Coal Development and Utilization", Directorate General of Min. and Coal, No. b, Jakarta, Indonesia, 2021.
[3] R. Prabowo, I. Prengki, "Decreasing the Ash Coal and Sulfur Contents of Sawahlunto Subbituminous Coal by Using Minyak Jelantah", IOP Conference Series: Earth and Environmental Sci., Vol. 413, No. 1, pp. 34-40, 2020.
[4] C. Cerik, V. Arslan, "The Modelling of Fine Coal Beneficiation with A Water-Only Cyclone", Gospodarka Surowcami Mineralnymi - Mineral Resources Management, Vol. 38, No. 3, pp. 137-150, July 2023.
[5] E. Sanwani, A. Ibrahim, A. Sudarsono, I. Handayani, "Coal Washing", Department of Mining Engineering, Bandung Institute of Tech., Bandung, Indonesia, 1998.
[6] R.G. Abaszade, A.G. Mammadov, V.O. Kotsyubynsky, E.Y. Gur, I.Y. Bayramov, E.A. Khanmamadova, O.A. Kapush, "Modeling of Voltage-Ampere Characteristic Structures on The Basis of Graphene Oxide/Sulfur Compounds", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 51, Vol. 14, No. 2, pp. 302-306, June 2022.
[7] A. Nelvi, A. Fadhly, J.A. Wardani, H. Rahmi, "Optimization of Calorific Value and Ash Content of Brown Coal Using Crude Lime-Palm Oil-Water Agglomeration Method", Mining Journal, Vol. 6, No. 4, pp. 178-183, February 2023.
[8] M. Ozer, O.M. Basha, B. Morsi, "Coal-Agglomeration Processes: A Review", International Journal of Coal Preparation and Utilization, Vol. 37, No. 3, pp. 131-167, May 2017.
[9] Nukman, S. Poertadji, "Reduction of Ash and Sulphur Content in Sub Bituminous Coal by Palm Oil-Water Agglomeration Method", Indonesian Journal of Materials Science, Vol. 7, No. 3, pp. 31-36, 2006.
[10] S. Wang, X. Tao, "Effect of Surfactants on The Flotation Performance of Low-Rank Coal by Particle Sliding Process Measurements", Mineral Resources Management, Vol. 34, No. 1, pp. 69-82, 2018.
[11] M. Arifin, E. Sanwani, S.K. Chaerun, "Removal of Sulfur and Ash from Indonesian Coal by Indigenous Mixotrophic Bacteria", Current Research on Biosciences and Biotech., Vol. 1, No. 2, pp. 71-76, February 2020.
[12] S.R. Nurhawaisyah, E. Sanwani, S.K. Chaerun, M. A. Rasyid, "Clean Coal Technology Using an Iron and Sulfur-Oxidizing Mixotrophic Bacterium", IOP Conf. Ser. Mater. Sci. Eng., Vol. 478, No. 34, pp. 103-109, 2019.
[13] ASTM D3173/D3173M-17a, "Standard Test Method for Moisture in The Analysis Sample of Coal and Coke", ASTM Internation., West Conshohocken, PA, USA, 2017.
[14] ASTM D3175-18, "Standard Test Method for Volatile Matter in The Analysis Sample of Coal and Coke", ASTM International, West Conshohocken, PA, USA, 2018.
[15] ASTM D5142-09, "Standard Test Method for Fixed Carbon in The Analysis Sample of Coal and Coke from Coal", ASTM International, West Conshohocken, PA, USA, 2009.
[16] ASTM D3174-12, "Standard Test Method for Ash in The Analysis Sample of Coal and Coke from Coal", ASTM Internation., West Conshohocken, PA, USA, 2012.
[17] ASTM D2492-02, "Standard Test Method for Sulfur in Coal", ASTM International, West Conshohocken, PA, USA, 2002.
[18] ASTM D2015-00, "Standard Test Method for Gross Calorific Value of Coal and Coke by The Adiabatic Bomb Calorimeter", ASTM International, West Conshohocken, PA, USA, 2000.
[19] R. Pratama, Sufriadin, S. Widodo, "Study of Increasing the Calorific Value of Coal Using Waste

Cooking Oil", IOP Conf. Ser. Earth Environ. Sci., Vol. 1134, No. 1, pp. 78-82, January 2023.
[20] M. Irsyad, A. Amrizal, M.D. Susila, A. Amrul, T.M. Fransisco, "Heat Transfer Characteristics of Coconut Oil as Phase Change Materials in Freezing Process", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 50, Vol. 14, No. 1, pp. 29-33, March 2022.
[21] A. Aladin, "Empirical Modelling of Coal Desulphurisation by Flotation with Rayleigh Method", Journal of Chemical Process Engineering, Vol. 5, No. 1, pp. 45-53, 2020.
[22] A. Aladin, "Determination of the Optimum Ratio of CPO: Coal in Desulphurisation and Deashing by Continuous Flotation System", Journal of Process Engineering, Vol. 3, No. 2, pp. 50-56, 2009.
[23] N.M.N.W.H.H. Agung, "Relationship between Total Sulphur Content and Gross Calorific Value of Coal PT. Carsurin Samarinda", Journal of Mineral Technology, Vol. 7, No. 1, pp. 1-8, 2019.

BIOGRAPHIES

Name: **Nurliah**
Surname: **Jafar**
Birthday: 29.09.1984
Birthplace: Barru, Indonesia
Bachelor: Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, 2008
Master: Mineral and Metallurgical Engineering, Mining Engineering Department, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Bandung, Indonesia, 2014
The Last Scientific Position: Lecturer, Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, Since 2009
Research Interests: Exploration Mining
Scientific Publications: 38 Researches
Scientific Memberships: Indonesia Engineering Association, Indonesia Lecturer Association, Young Engineers Forum Indonesia Engineering Association, Association of Mining Experts Indonesia

Name: **Muhammad**
Middle Name: **Idris**
Surname: **Juradi**
Birthday: 12.02.1992
Birthplace: Malili, Indonesia
Bachelor: Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, 2014
Master: Mineral and Metallurgical Engineering, Mining Engineering Department, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Bandung, Indonesia, 2017
The Last Scientific Position: Lecturer, Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, Since 2016
Research Interests: Mining Environment, Minerals Processing
Scientific Publications: 22 Papers, 4 Projects
Scientific Memberships: Indonesia Engineering Association, Indonesia Lecturer Association, Young Engineers Forum Indonesia Engineering Association, Association of Mining Experts Indonesia

Name: **Suriyanto**
Surname: **Bakri**
Birthday: 19.11.1986
Birthplace: Sidrap, Indonesia
Bachelor: Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, 2009
Master: Mineral and Metallurgical Engineering, Mining Engineering Department, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Bandung, Indonesia, 2018
The Last Scientific Position: Lecturer, Department of Mining Engineering, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, Since 2018
Research Interests: Mining Environment, Minerals Processing
Scientific Publications: 29 Papers, 3 Projects
Scientific Memberships: Indonesia Engineering Association, Indonesia Lecturer Association, Young Engineers Forum Indonesia Engineering Association, Association of Mining Experts Indonesia

Name: **Lamatinulu**
Birthday: 08.06.1969
Birthplace: Palopo, Indonesia
Bachelor: Industrial Engineering and Management, Industrial Engineering Department, Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, 1994
Master: Industrial Management, Department of Industrial Engineering, Faculty of Industrial Technology, Ten November Institute of Technology, Surabaya, Indonesia, 2002 Technology, Muslim of Indonesia University, Makassar, Indonesia, 1994
Doctorate: Manufacturing Industrial Engineering, Mechanical Engineering Department, Faculty of Engineering, Brawijaya University, Malang, Indonesia, 2018
The Last Scientific Position: Prof., Department of Engineering Faculty of Industrial Technology, Indonesian Muslim University, Makassar, Indonesia, Since 2007
Research Interests: Operation Research, Performance Measurement, Product Development, Production Planning and Control
Scientific Publications: 30 Papers, 3 Books, 5 Projects
Scientific Memberships: Indonesian Engineers Association, Indonesian Lecturer Association