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Research Article

Investigation and Comparison of the Enrichment Potential of Turkey (Şenkaya, Erzurum) Coals with Knelson Concentrator

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The quality of coals from, Erzurum varies widely. Two coal samples from this area were compared. The first has a composition of 19% ash, 5700 kcal, and 3% sulfur while the other has 49.20% ash, 3000 kcal, and 1.6% sulfur composition. It is understood that the first coal sample is a high-quality coal. Although the ash content of the second coal sample is determined to be high and the calorie value is low, the low sulfur content is advantageous for the environment. This study aimed at increasing the quality of coal samples by carrying out experiments for reducing the ratio of ash and sulfur with Knelson's enrichment processes. Chemical analysis, sieve analysis experiments, %ash, %moisture, and %calorie values of each fraction are determined from two different C1 and C2 coal samples taken from the Balkaya village belonging to Şenkaya, Erzurum. Then, %ash, %yield, and %sulfur analyzes were carried out on the coal samples using the Knelson gravity separator enrichment method, and the results were evaluated for coal samples.

1. Introduction

The Knelson concentrator is a vertical axis bowl-type centrifugal concentrator that uses a fluidized bed to perform its concentrating duty. It was first introduced as a semibatch unit in 1982 and has gone through several iterations of design, leading to the development of a continuous discharge machine [1]. Feed is introduced in the form of slurry at the bottom of the unit through a central tube. A theoretical centrifugal force of around 60 G gauses the feed materials to fill the interriffle spaces from bottom to top. Once these spaces are full of solids, the introduction of further feed material starts the sorting stages, where heavy minerals displace the light minerals and as a result, the heavy minerals are trapped in the interriffle spaces while the lighter minerals are carried by water to the top of the unit; hence, separation occurs. To keep the bed of heavy minerals formed thus fluidized, water is introduced through the multiple fluidization holes in the inner shell. This fluidization water force is expected to be strong enough to inhibit severe compaction of the heavy mineral bed due to the strong centrifugal force [2, 3]. The performance evaluation of Knelson concentrators treating various minerals, coals, and heavy metal recovery has become an active research topic [3]. The Knelson concentrator was used to remove ash and sulfur from oxidized fine coal. Effects of coal particle size, bowl speed, and fluidizing water pressure were studied. Considerable levels of ash and pyritic sulphur were rejected from the coal. Performance of the process was affected by all of the variables [4]. An attempt has been made to understand the separation characteristics of coal fines in a Knelson concentrator. It has been revealed that this equipment can produce a clean coal ash content of 17% from a feed coal ash content of around 36% [5]. Coal recovery was increased by 10 to 20 absolute percentage points, while a 2% point drop in the minimum product ash content was also achieved [6]. Highly efficient rejections of both ash and sulfur from fine coal have been reported for the Knelson concentrator [7, 8]. Reference is also made to the development of the continuous Knelson concentrator designed for the concentration of base metals and segregation of contaminating elements from finely classified coal [9]. A pilot scale, continuous discharge model of Knelson concentrator was installed in an eastern U.S. coal preparation plant [10]. From the results of a study, test data showed that a Knelson concentrator could provide more efficient separation than flotation when cleaning coal in the 25 × 150 mm particle size range [11]. The continuous Knelson concentrators have been successfully used in the mineral processing industry, especially for heavy minerals separation. The potential applications could be coal cleaning and solid waste separation as other gravity separators have been used [12–14]. Relatively, little information is available regarding the size-by-size performance of the Knelson concentrator since this unit was only recently introduced to the coal industry. However, data obtained at Southern Illinois University (SIU) using an Illinois No. 5 seam coal suggest that this separator is capable of maintaining good recoveries (90%) and rejections of ash (55%) and sulfur (45–55%) over the size range from 28 to 400 mesh. Although data are not yet available regarding the performance of the unit in treating 400 mesh × 0 material, it is expected to be subjected to the same limitations as the other enhanced gravity concentrators [15]. The Knelson concentrator is another gravity-based separator which has been widely applied in coal beneficiation [4–6, 16]. The Knelson concentrator utilizes the principle of hindered settling and centrifugal force. It consists of a central perforated cone containing horizontal ribs along the inside wall. As a result, the mineral grains remain mobile, allowing more heavy particles to penetrate the fluidized bed [17]. As the magnitude of the applied centrifugal force increases, the size of the particles to be recovered becomes smaller [18, 19].

The Knelson continuous variable discharge (CVD) concentrator was developed to address specific mineral recovery applications which are amenable to enhanced gravity separation but, due to the comparatively high content of the target mineral, are not practical for conventional batch-type concentration methods. The Knelson CVD concentrator is also the only continuous centrifugal concentrator available that utilizes Knelson's widely proven patented fluid bed technology. While CVD technology is suitable for selected precious metal recovery applications, the technology is primarily utilized as a rougher concentrator used in the bulk recovery of various base metals and industrial minerals. The continuous technology differs from the semicontinuous (batch) technology by delivering a continuous stream of concentrate. The CVD will discharge the concentrate while simultaneously processing fresh feed, whereas semicontinuous units must be stopped intermittently to remove the concentrate. The Knelson CVD concentrators are suited to applications where the target mineral exceeds 0.5% of the total feed solids. The cleaning of ash from fine coal typically utilizes cyclones, spirals, and flotation as the major units in an operation. Flotation is ineffective when oxidized coal is encountered, leading to significant losses in fine coal. The Knelson continuous variable discharge (CVD) concentrator is an enhanced gravity device where the separation mechanism is not affected by surface chemistry as in flotation. The CVD can potentially revolutionize fine coal washing circuits by eliminating the need for some or all of these unit operations. The advantages of CVD include the following: it can achieve effective ash and sulfur rejection in fine coal streams utilizing patented fluidized bed technology in an enhanced gravity centrifuge; it may replace cyclones, spirals, and flotation; it can increase fine coal yield and maintain coal specification in the fine fraction (−1 mm), and the CVD can handle high tonnage in a small footprint (up to 100 tonnes/hour in a single CVD); it uses no reagents thereby minimizing environmental concerns; it can be accurately optimized to achieve desired separation results; and it provides high operational availability at minimal cost. Pilot scale lab testing was performed on a metallurgical coal by a third-party laboratory. The results from this test program displayed high clean coal yields within the target ash range. Tests on minus 1 mm fine coal reduced the ash content from 20 to 12.6% with yields ranging from 70 to 86%. Production CVDs are expected to achieve superior results [20]. Sakuhuni investigated to develop a bench-scale test to predict applicability of CVD, to develop a process optimization approach that considers more than one performance objective, to develop a novel approach to select operating conditions that optimize performance for a CVD, and to provide clarity on the interaction between control parameters and performance indicators [21].

Coal spirals, flotation, leaching, jig, shaking table, water cyclones, Knelson, Falcon, MGS (multigravity separator), TBS (teeter bed separator), and Reflux classifier devices are also used in the enrichment of fine-grained coals. The Knelson gravity separator can be distinguished by the difference in density and centrifugal forces between coal-mudstone in the enrichment of fine-grained coal. However, the use of this device is not too common in coal. If the importance of this study is emphasized, there is limited evidence that the coals can be enriched with Knelson separator. This study aims at reducing these ratios because of the high percentage content of sulfur and ash which adversely affect the quality of coal. Also, in this study, Erzurum/Şenkaya coals were investigated by using Knelson gravity separator. It is concluded that the Knelson separator can be used to enrich coal and for %sulfur reduction. Further research may be required to find out if the Knelson separator can be used in fine-grained coal washing methods by changing the operating parameters.

2. Materials

The Şenkaya/Balkaya basin is located within 60 kilometers of the northeastern Gollet to the southwestern Oltu river source area in the Erzurum Province. The Balkaya basin is surrounded by Mesozoic and Paleozoic lands of Eastern Anatolia [22]. The Balkaya-Oltu pit, where the Balkaya basin is located, is surrounded by the Northern Anatolian Alpine Folds and is a tectonic depression with significant vertical offsets of the faults that limit the pit. For example, a vertical strike of 1000 meters is seen between the coal beds near Oltu. The Şenkaya basin consists of the following structures: brown-colored, red-colored, and green-colored marls and limestones; white-colored, red-colored, and light green-colored marly and clay with salt and gypsum; 2-3 green-dark gray-colored and glaucony gray-colored fine-grained veins of conglomerate series; light gray-, light green-, and yellow-colored marls; and leaf-shaped schist marl. Also, there are fine grains and limestone interlayers and marly schist lignite veins with freshwater fossils [23, 24]. Figure 1 shows Erzurum/Şenkaya coals storage area.

In this study, Erzurum/Şenkaya Balkaya village Coal samples taken from 2 different mining quarries were named Sample-C1 and Sample-C2. The point coordinates are given in Tables 1 and 2.

2.1. Sample-C1 Coal. Coal samples contain pyrite, calcite, quartz, and amorphous material. The chemical analysis results of Sample-C1 coal are shown in Table 3. According to the results of the chemical analysis, a low value of 19.94% ash and a high calorific value of 5690 kcal were obtained. However, a 3.24% sulfur composition is not very high. For this reason, the enrichment experiments to be carried out on the C1 coal sample will reduce both the quality of the coal and the environmental damage.

After the chemical analysis of the coal sample was performed, the Sample-C1 was subjected to sieve analysis experiments using 8 different particles. The grain size distribution curves are plotted in Table 4, Figure 2 shows the sieve analysis table of the coal sample which is broken down to 5 mm with the jaw crusher, and Figure 2 shows the coal sieve analysis curve which is lowered to 5 mm with the jaw crusher. From Table 4, the highest interpreted %weight ratio was found to be between −3.35 + 0.5 mm and the lowest % weight ratio was determined as +4.76 mm and −0.106 mm.

Table 5 shows Sample-C1 coal sieve analysis (%ash, % moisture, and %calorie) values for each grain fraction. When the results are examined, the highest value of 25.24% ash was found in −0.106 mm size and the second highest value was found as 22.39% ash in the high dimension of +4.76 mm. The lowest ash content is found to be in the fraction of the grain size between −2 + 1 mm. When 19.94% ash value of the feeding material is considered, the highest calorific value in grain fractions between −3.35 + 0.3 mm is observed. However, the sulfur content was determined as 3.24%.

2.2. Sample-C2 Coal. Table 6 gives the results of Sample-C2 coal chemical analysis. According to the results of the chemical analysis, an ash content of 49.20% can be considered to be very high and a calorific value of 3040 kcal may be considered low. However, the sulfur content of 1.62% is low value. The quality of the enrichment tests to be applied to the Sample-C2 coal can be used to reduce the ash ratio and to increase the %calorie proportionally, which will enable effective and efficient consumption.

Sample-C2 sieve analysis was performed for 4 different fractions between 0.500 and 0.106 mm grain size. Table 7 shows Sample-C2 screen analysis values. Figure 3 shows Sample-C2 coal screen analysis graphic. Table 7 and Figure 3 are interpreted together; % weight ratios were found to be the highest −0.106 mm, and the lowest % weight ratios were found to be +0.500 mm.

Table 8 shows Sample-C2 coal sieve analysis (%ash % moisture %calorie) values for each grain fraction. When the results are examined; 49.20% ash value in the size of feed sample and 49.17% ash value in the second highest −1+0.5 mm grain size were obtained. The lowest ash content

Figure 1: Erzurum/Şenkaya coals storage area.

Table 1: Sample-C1 coal sample point coordinates.

Point name	Y	X	Height
1	38T 468 551 D	45 12 950K	1370 m
2	38T 468 573 D	45 12 938K	1370 m
3	38T 468 528 D	45 12 930K	1370 m
4	38T 468 590 D	45 12 934K	1370 m
5	38T 468 558 D	45 12 950K	1370 m

Table 2: Sample-C2 coal sample point coordinates.

Point name	Y	X	Height
1	38T 268 230 D	45 195 5K	1357 m
2	38T 268 244 D	45 195 8K	1357 m
3	38T 268 820 D	45 195 7K	1357 m
4	38T 268 224 D	45 195 4K	1357 m
5	38T 268 245 D	45 195 6K	1357 m

Table 3: Chemical analysis results of Sample-C1 coal [24].

	Original base	Air-dry base	Dry base
Moisture (%)	6.61	6.35	—
Ash (%)	19.94	20.00	21.36
Volatile matter (%)	33.68	33.77	36.06
Fixed carbon (%)	39.77	39.88	42.58
Total	100.00	100.00	100.00
Total sulfur (%)	3.25	3.26	3.47
Lower heat value (kcal/kg)	5458	5475	5887
Upper heat value (kcal/kg)	5690	5706	6094

Table 4: Sample-C1 screen analysis values.

Particle size (mm)	Weight (%)	Under the sieve (%)	Over the sieve (%)
+4.76	2.34	100.00	2.34
−4.75 + 3.35	10.88	97.66	13.22
−3.35 + 2	24.11	86.78	37.33
−2.0 + 1.0	23.58	62.67	60.91
−1 + 0.5	15.60	39.09	76.50
−0.5 + 0.3	8.31	23.50	84.81
−0.3 + 0.106	10.65	15.19	95.46
−0.106	4.54	4.54	100.00
Total	100		

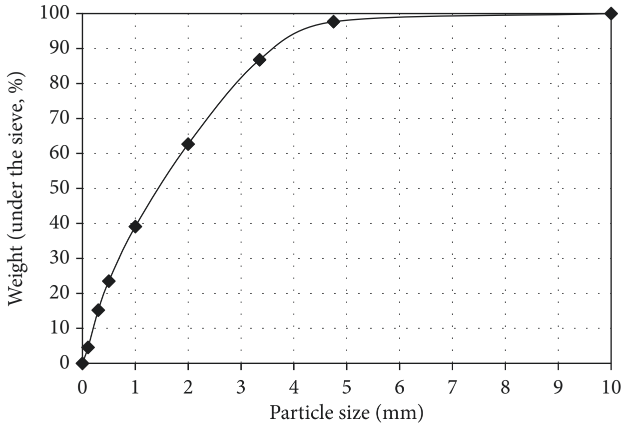


Figure 2: Sample-C1 coal screen analysis graphic.

Table 5: Sample-C1 screen analysis: ash, moisture, and calorie values.

Particle size (mm)	Ash (%)	Moisture (%)	Calorie (kcal)	Sulfur (%)
Feed sample	19.94	6.61	5690	3.24
+4.76	22.39	6.58	5604	
−4.76 + 3.35	19.16	6.68	5844	
−3.35 + 2	16.91	6.36	5993	
−2 + 1	16.06	6.40	6040	
−1 + 0.5	16.40	6.35	6015	
−0.5 + 0.3	18.85	5.94	5985	
−0.3 + 0.106	19.25	6.06	5815	
−0.106	25.24	5.04	5104	

Table 6: Chemical analysis results of Sample-C2 coal.

	Original base	Air-dry base	Dry base
Moisture (%)	7.25	6.97	—
Ash (%)	49.20	49.35	53.11
Total sulfur (%)	1.62	1.62	1.74
Calorie lower heat value (kcal/kg)	2885	2895	3158
Calorie upper heat value (kcal/kg)	3040	3050	3280

Table 7: Sample-C2 screen analysis values.

Particle size (mm)	Weight (%)	Under the sieve (%)	Over the sieve (%)
+0.500	11.06	100	11.06
−0.500 + 0.300	16.30	88.94	27.36
−0.300 + 0.106	29.84	72.64	57.20
−0.106	42.80	42.80	100
Total	100		

is conflicting with 42.18% in the fraction of the grain size between −0.5 + 0.106 mm. As a result, it was found that the highest calorific value in particle fractions below −0.5 + 0.106 and −0.106 mm. Although the % ash content in this coal sample is high, the low % S ratio provides a significant advantage for coal.

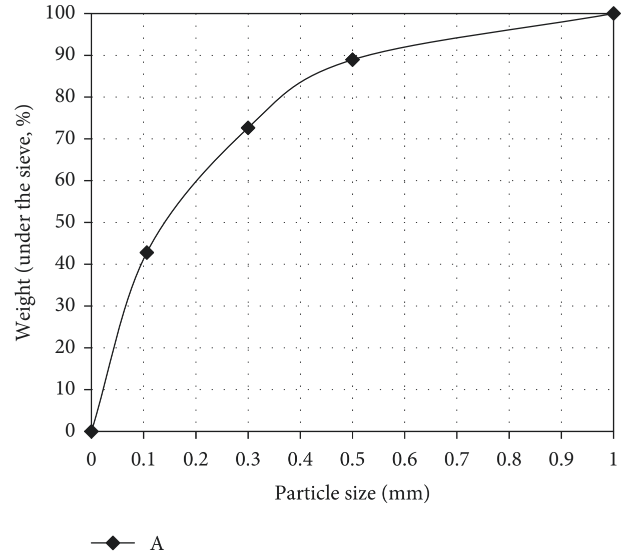


Figure 3: Sample-C2 coal screen analysis graphic.

Table 8: Sample-C2 screen analysis: ash, moisture, and calorie values.

Particle size (mm)	Ash (%)	Moisture (%)	Calorie (kcal)	Sulfur (%)
Feed sample	49.20	6.97	3050	1.62
+1.00	46.85	6.38	3276	
−1 + 0.5	49.17	6.45	3065	
−0.5 + 0.106	42.18	6.52	3565	
−0.106	45.07	6.07	3385	

3. Methods

3.1. Enrichment of the Coal Samples with the Knelson Concentrator. The Knelson concentrator experiments were performed with the KC-MD3 model laboratory-type instrument. The centrifugal force parameters used were 14 G(398 rpm), 24 G(530 rpm), 40 G(685 rpm), and 60 G(839 rpm), and the wash water pressure parameters were determined as 2 PSI in preliminary experiments using homogeneously divided test specimens after sample preparation. Figure 4 shows a photograph of the KC-MD3 model laboratory-type Knelson gravity concentrator. All experiments were carried out at the Dokuz Eylül University, Department of Mining Engineering. Table 9 gives the technical specifications of a laboratory-type KC-MD3 Knelson device.

In the Knelson gravity enrichment experiments, Sample-C1 and Sample-C2 coals were subjected to 14 G (398 rpm), 24 G (530 rpm), 40 G (685 rpm), and 60 G (839 rpm) strength tests separately. Then, for each sample, %ash and % sulfur charts were drawn by calculating coal sample, concentrate and %weight, and %yield tables separately, and the results were interpreted using tables and graphics.

3.1.1. Enrichment of Sample-C1 Coal (0.5–0.106 mm). Sample-C1 coal was fed to the Knelson gravity separator in particle size of −0.5 + 0.106 mm. Table 10 shows enrichment

Figure 4: Experimental KC-MD3 model laboratory-type Knelson gravity concentrator.

concentration values of Sample-C1 coal with the Knelson method for particle sizes −0.5 + 0.106 mm. Figure 5 shows enrichment concentration graphic of Sample-C1 coal with the Knelson method for particle sizes −0.5 + 0.106 mm. Figure 6 shows Sample-C1 Knelson gravity %ash and %S analysis chart for particle sizes 0.5–0.106 mm. According to this, with 26% efficiency in concentrate compared to the result of a 14 G powered device, 43.1% yield was obtained in the concentrate according to 60 G result.

As a result, it has been estimated that the lowest ash content is obtained at 14.8% and at 14 G rotational speed. When the %S ratios were examined, it was observed that the decrease was generally observed at 24 G, and the lowest value was found at 2.85% at the working power. It can be said that both the %ash and the %S values are positive results with the Knelson concentrator.

3.1.2. Enrichment of the Sample-C2 Coal (−1+0.5 mm). Sample-C2 coal was fed to the Knelson gravity separator in particle size of 1–0.5 mm. Table 11 shows enrichment concentration values of Sample-C2 coal with the Knelson method for particle size −1+0.5 mm. Figure 7 shows enrichment concentration graphic of Sample-C2 coal with the Knelson method for particle size −1+0.5 mm. Figure 8 shows Sample-C2 Knelson gravity %ash and %sulfur analysis chart for particle size −1+0.5 mm. According to this, in the 60 G working force, 28.7% yield was obtained in the concentrate, and the highest value was obtained in reverse proportion and with the efficiency of 14 G working power as 41.6%. It was also determined that the sulfur percentages obtained in the concentrate decreased by % by weight. According to the results, it was determined that the enrichment result of C2 sample was positive, and the decrease in ash and sulfur values was observed with the Knelson gravity separator.

3.1.3. Enrichment of Sample-C2 Coal (0.500–0.106 mm). Sample-C2 coal was fed to the Knelson gravity separator in particle size of 0.5–0.106 mm. The C2 sample of 0.500–0106 mm was again enriched with a Knelson concentrator separator. Table 12 shows enrichment concentration values of Sample-C2 coal with the Knelson method for particle size −0.5 + 0.106 mm. Figure 9 shows enrichment concentration graphic of Sample-C2 coal with the Knelson method for −0.5 + 0.106 mm. Figure 10 shows Sample-C2 Knelson gravity %ash and %sulfur analysis chart for −0.5 + 0.106 mm. According to this, the highest value was obtained at 14 G working power with 44.6% efficiency in the concentrate. According to the results of the experiment, it was found that the rate of 24 G was 42.8% in the working power, 40.8% in the 40 G, and 35.9% in the 60 G. When the ash and sulfur values are examined, it is seen that there is a general decrease. This shows that the enrichment studies with the Knelson separator have been successful. It has been determined that the lowest value of ash is 35.2% and 60 G.

4. Conclusions

Coal samples taken from the Erzurum/Şenkaya region have been subjected to enrichment processes with ore preparation and Knelson gravity concentrator separator. According to the obtained analysis, graph, and results, it was observed that coal samples named C1 and C2 could be enriched with the Knelson gravity separator. It can be said that the ash and sulfur percentages are falling and the coal quality is increasing.

According to chemical analysis of the C1 sample, 19.94% ash, 3.24% sulfur, and 5458 kcal were detected. According to the analysis results of the sieves made between 4.76 mm and 0.106 mm, it was determined that the material weight was the highest at −3.35 + 0.5 mm and the lowest % weight ratio at +4.76 mm and −0.106 mm.

According to the results of chemical analysis of the C2 sample, 49.20% ash, 1.62% sulfur, and 3040 kcal were calculated. Then, chemical analyzes of the samples were made for each grain fraction between −0.5 mm + 0.106 mm, % weight ratios were found to be the highest −0.106 mm, and the lowest % weight ratios were found to be for +0.500 mm particle size.

The highest value was obtained with a yield of 43.05% in the concentrate according to 60 G results on the C1 sample (0.500–0.106 mm). It has been estimated that the lowest ash content is obtained at 14.8% at 14 G power. When the %S ratios were examined, it was observed that the overall decrease was 24 G and the lowest value was 2.85% in the working power.

Sample-C2 coal (−1+0.500 mm) with Knelson produced at least 28.7% yield in the concentrate at 60 G operating parameters and the highest value at 14 G yield with 41.6% yield. When the values of ash and sulfur are examined, a general decrease is seen. According to the results, it was determined that the enrichment result of the C2 sample was positive, and a decrease in ash and sulfur values was observed. It has been determined that ash and sulfur ratios decrease in the proportion of 14 G, 24 G, 40 G, and 60 G in the C1 sample, while the productivity increases in direct proportion to the working power. On the C2 side, the reverse was the case with 60 G, 40 G, 24 G, and 14 G increased yield

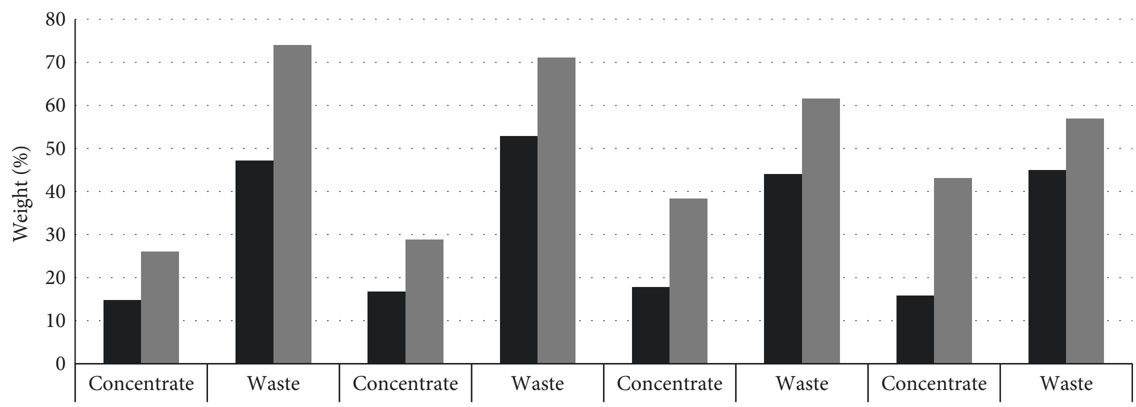
Table 9: Technical specifications of KC-MD3 model laboratory-type Knelson concentrator.

Motor power	Capacity	Pulp solid ratio	Max. feed size	Max. water pressure	Max. rotation	Max. power
1/6 (hp)	0–45 (kg/h)	0–75 (%)	1.7 (mm)	30 (psi)	2300 (rpm)	150 (G)

Table 10: Enrichment concentration values of Sample-C1 coal with Knelson method (−0.5 + 0.106 mm).

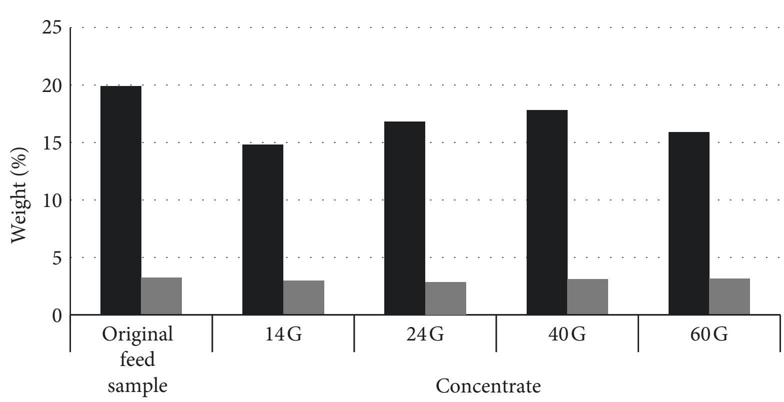
Rotational speed	Test product	Weight (%)	Ash (%)	Yield (%)	Sulfur (%)
14 G (398 rpm)	Concentrate	56.06	14.76	26.00	2.97
	Waste	43.94	47.17	74.00	—
	Feed sample	100	19.94	100	3.24
24 G (530 rpm)	Concentrate	56.13	16.80	28.89	2.85
	Waste	43.87	52.90	71.11	—
	Feed sample	100	19.94	100	3.24
40 G (685 rpm)	Concentrate	60.60	17.79	38.37	3.13
	Waste	39.40	43.95	61.63	—
	Feed sample	100	19.94	100	3.24
60 G (839 rpm)	Concentrate	68.10	15.94	43.05	3.15
	Waste	31.90	45.02	56.95	—
	Feed sample	100	19.94	100	3.24

Feeds in the experiments are 100 g each.



	14G Concentrate	14G Waste	24G Concentrate	24G Waste	40G Concentrate	40G Waste	60G Concentrate	60G Waste
Ash (%)	14.8	47.2	16.8	52.9	17.8	44	15.9	45
Yield (%)	26	74	28.9	71.1	38.4	61.6	43.1	57

Figure 5: Enrichment concentration graphic of Sample-C1 coal with Knelson method (−0.5 + 0.106 mm).



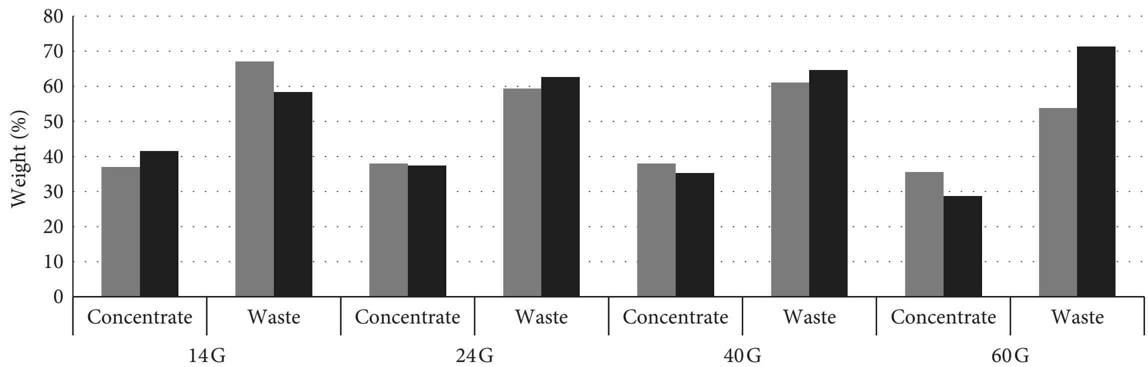
	Original feed sample	14G	24G	40G	60G
Ash (%)	19.9	14.8	16.8	17.8	15.9
Sulfur (%)	3.24	2.97	2.85	3.13	3.15

Figure 6: Sample-C1 Knelson gravity ash % and sulfur % analysis chart (−0.5 + 0.106 mm).

Table 11: Enrichment concentration values of Sample-C2 coal with Knelson method (−1+0.5 mm).

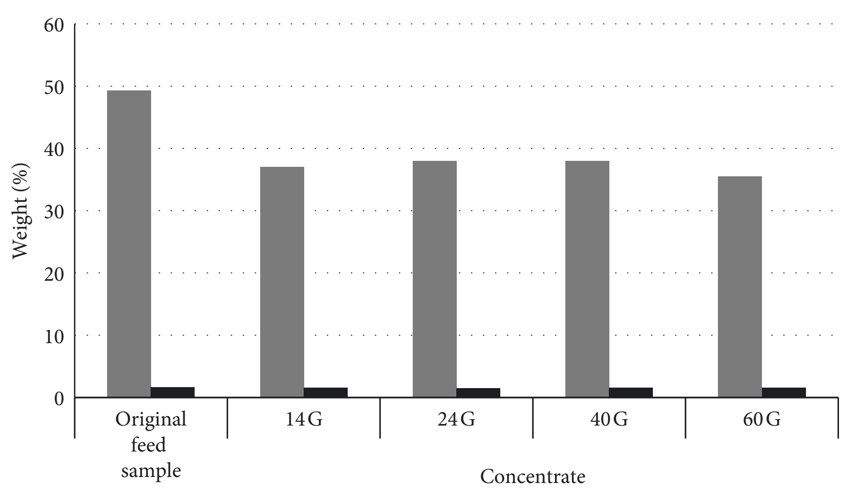
Rotational speed	Test product	Weight (%)	Ash (%)	Yield (%)	Sulfur (%)
14 G (398 rpm)	Concentrate	56.38	36.98	41.62	1.54
	Waste	43.62	67.05	58.38	1.71
	Feed sample	100	49.20	100	1.63
24 G (530 rpm)	Concentrate	48.31	37.95	37.41	1.50
	Waste	51.69	59.35	62.59	
	Feed sample	100	49.20	100	1.63
40 G (685 rpm)	Concentrate	46.69	37.96	35.27	1.57
	Waste	53.31	61.02	64.73	
	Feed sample	100	49.20	100	1.63
60 G (839 rpm)	Concentrate	37.92	35.46	28.72	1.55
	Waste	62.08	53.76	71.28	
	Feed sample	100	49.20	100	1.63

Feeds in the experiments are 130 g each.



	14G Concentrate	14G Waste	24G Concentrate	24G Waste	40G Concentrate	40G Waste	60G Concentrate	60G Waste
Ash (%)	37	67.1	38	59.4	38	61	35.5	53.8
Yield (%)	41.6	58.4	37.4	62.6	35.3	64.7	28.7	71.3

Figure 7: Enrichment concentration graphic of Sample-C2 coal with Knelson method (−1+0.5 mm).



	Original feed sample	14G	24G	40G	60G
Ash (%)	49.3	37	38	38	35.5
Sulfur (%)	1.63	1.54	1.5	1.57	1.55

Figure 8: Sample-C2 Knelson gravity ash % and sulfur % analysis chart (−1+0.5 mm).

in the concentrate at working power. It was observed that the lowest ash content is provided by 35.5% and 60 G work.

According to the results of enrichment of Sample-C2 (−0.500 + 0.106 mm) coal sample with Knelson, the highest value was obtained at 14G working power with 44.57% efficiency in concentrate. The yield values were found to be 42.8% in 24G working power, 40.8% in 40G, and 35.9% in 60G. When the ash and sulfur values are examined, it is seen that

Table 12: Enrichment concentration values of Sample-C2 coal with Knelson method (−0.5 + 0.106 mm).

Rotational speed	Test product	Weight (%)	Ash (%)	Yield (%)	Sulfur (%)
14 G (398 rpm)	Concentrate	60.13	36.11	44.57	1.52
	Waste	39.87	67.74	55.43	—
	Feed sample	100	49.25	100	1.63
24 G (530 rpm)	Concentrate	55.85	36.17	42.81	1.55
	Waste	44.15	61.12	57.19	—
	Feed sample	100	49.25	100	1.63
40 G (685 rpm)	Concentrate	53.60	37.15	40.83	1.57
	Waste	46.40	62.20	59.17	—
	Feed sample	100	49.25	100	1.63
60 G (839 rpm)	Concentrate	48.50	35.24	35.92	1.50
	Waste	51.50	59.28	64.08	—
	Feed sample	100	49.25	100	1.63

Feeds in the experiments are 100 g each.

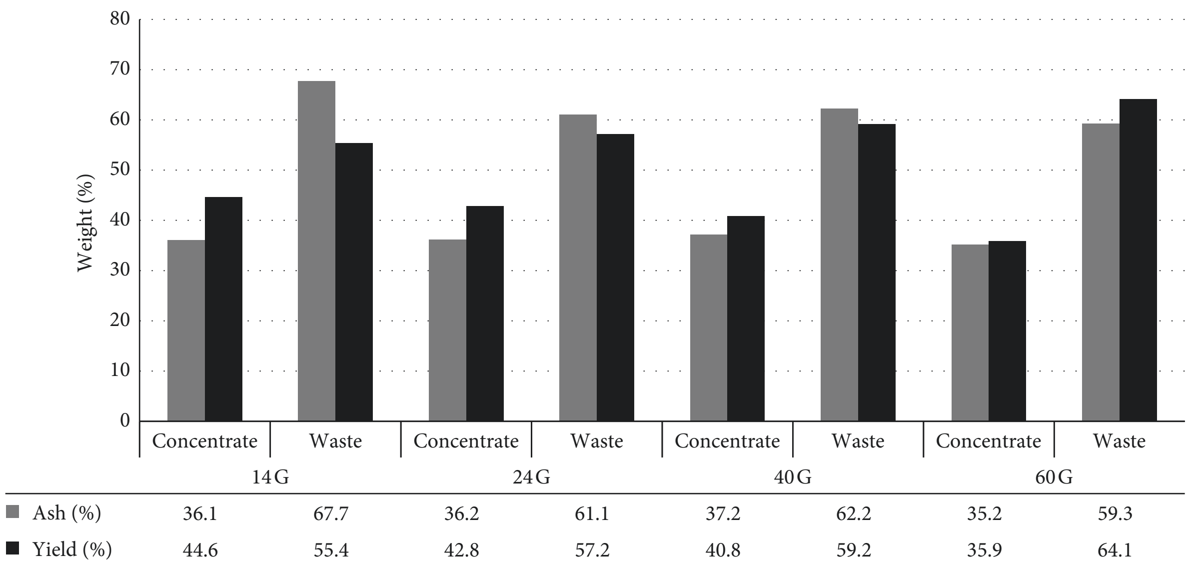


Figure 9: Enrichment concentration graphic of Sample-C2 coal with Knelson method (−0.5 + 0.106 mm).

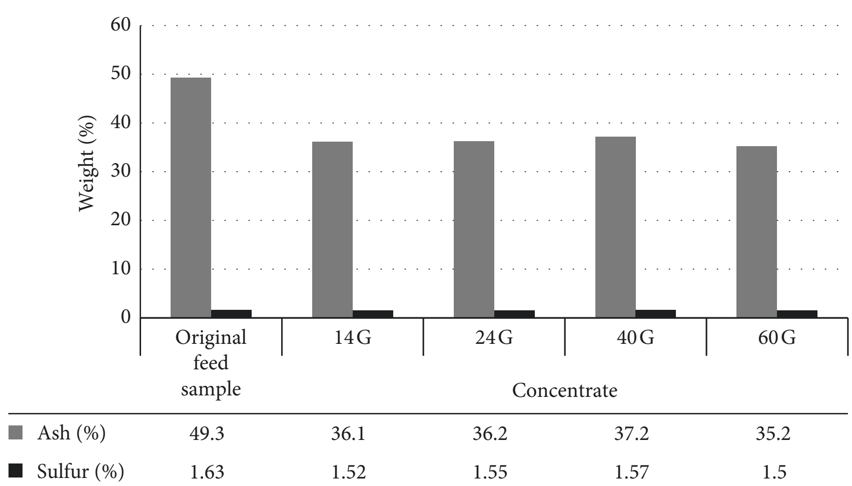


Figure 10: Sample-C2 Knelson gravity ash % and sulfur % analysis chart (−0.5 + 0.106 mm).

there is a general decrease. This shows that the enrichment studies with the Knelson separator have been successful. It has been determined that the lowest value of ash is 35.2% and 60 G. For Sample-C2 (−1 + 0.500 mm) and Sample-C2 (−0.500 + 0.106 mm), the result is the same as the values and results are similar for the Knelson gravity separator.

Figure 6 shows Sample-C1 Knelson gravity %ash and % sulfur analysis chart ($-0.5+0.106$ mm), while the sulfur content of the original feed material was 3.24%; it was 2.97% in 14 G operating performance, 2.85% sulfur content at 24 G rotation speed, 3.13% S at 40 G operating performance, and 3.15% sulfur content at 60 G. Figure 8 shows Sample-C2 Knelson gravity %ash and %sulfur analysis chart ($-1+0.5$ mm), while the % S ratio of the original feed was 1.63; it was observed that while the 14 G operating performance was 1.54, it was 1.55 in 60 G. Figure 10 shows Sample-C2 Knelson gravity ash and the S% analysis chart ($-0.5+0.106$ mm), while the % S ratio of the original feed is 1.63; it was observed that it decreases to 1.5 in 14 G and 60 G rotation speed performance. It can be concluded that the percentages of sulfur and ash decreased as a result of improving the quality of coal in this study.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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