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Briquetting of Afsin/Elbistan and Sorgun/Yozgat Lignites without Adding a Binder

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ABSTRACT: In this study, results of the cleaning and briquetting experiments of the lignite samples were presented. Basic aim of the work was to determine the binding effects of the humic acid contents of these lignite samples in the briquetting. Ash contents of the Afsin/Elbistan and Sorgun/Yozgat lignites were reduced to 29.8% and 14.8% respectively by the shaking table and flotation methods. The products cleaned were oxidized in atmospheric conditions in an oven at 90° C for the period of 48-192 hours. The oxidized samples were reacted with ammonium hydroxide (NH4OH) solution at again 90"C in a 2L laboratory reactor for one hour to generate ammonium humate, which was responsible for binding the coal particles into agglomerate. The green briquettes were heated from 135 to 175*C for one hour. The briquetting pressure was changed from 460 to 1565 kg/cm". In the end, although satisfactory mechanical resistances to the breakage were reached for both of the samples, water resistances of the briquettes obtained from the Afsin/Elbistan lignite were poor.

1 INTRODUCTION

There has been a long-felt need for a suitable, inexpensive and environmentally sound binder to consolidate the coal particles into weather- resistant agglomerates of convenient size for solid fuel use. Coal briquetting has generally been considered uneconomical for commercial-scale application. One of the impediments to coal agglomeration is the high cost of available hinders. Because coal is a relatively low-cost commodity, the binder must be low in cost and readily available to produce briquettes that are durable, moisture- resistant and should cause no hazardous environmental emissions during the combustion.

Many different binding materials have been used to facilitate the briquetting process in which it is responsible for increasing of cohesion forces between the particles of the briquetted materials. Conventional binders such as coal tar pitch provide strong briquettes. However, their use has been restricted due to their carcinogenic effects on human health and their contribution to air pollution. On the other hand some organic binders such as molasses, starch etc. provide poor moisture-resistant briquettes, and often subject to bacterial and fungal attack and may require the addition of environmentally 'unfriendly' biocides (Thomas et.al.. 1999).

Afsin/Elbistan and Sorgun/Yozgat lignites contain about 48%> and 16% humic acids respectively in organic base. It can easily be extracted after oxidation and alkali treatment operations. Binding property of ammonium humâtes has already been known (Wen, 1980; Yildirim and Ozbayoglu, 1995).

This work is basically considered with understanding the binding effect of the ammonium hydroxide soluble humic acid contents of these samples cleaned, which can be formed in the coal particles after the controlled aerial oxidation and ammoniation treatments. The nitric acid (HNOj) ajid alkali permanganate (KMnO.4) oxidation are much more rapid than the aerial oxidation, but the air as the agent is the cheapest and most widely available.

2 MATERIAL AND METHODS

2.1 Material

One of the samples used in the experimental works was taken from the size reduction input line of the Afsin/Elbistan power plant. The other sample was taken from the lump coal product of the Ayridam/Sorgun/Yozgat lignite deposit. Properties of the samples are shown in Table I.

Table 1. Proximate analyses of the R.O.M Atsın/Elbistan and Ayridani/Sorgun/Yozgat lignites

Contents	Elbistan lıenıte		Soreun leinte	
	Org" (%)	DB-(%)	Org[1] (%)	DB"(%)
Moisture	48 80	-	6.80	-
Ash	20.20	39.40	27 90	29.94
VM'	21 50	42.00	28.75	30 65
FC[4]	9.50	18.60	36.55	39.41
TS'	1.60	3.10	145	1.58 '
NCV"	940	1394	4380	4600

Original — [4]Fixed caibon
~Diy basis — Total sulphui
Volatile matter — "Net calorific value (kcal/kg)

2.2 Methods

2.2.1 Removal of ash

Inorganic mineral particles in the samples, which have higher specific gravities than the lignite particles were cleaned by a laboratory scale-shaking table. For this purpose, Afsin/Elbistan and Sorgun/Yozgat lignites were crushed and classified into -1.400+ 0.250 mm and -1.000+0.500 mm respectively. These fractions were fed to the table in the pulp form (12-15 lt./min. water flowrate) and the products were taken separately.

The -0.250 mm sized fraction obtained from the Afsin/Elbistan lignite was mixed with the table tailing and pulverized by wet grinding conditions in a ball mill to provide further liberation of the mineral matters (Figure I). Then, the ash making material in -0.074 mm sized product was cleaned by the agglo-flotation method. Here, fuel oil (No.6) containing *20'/i* kerosene was used as the agglomérant. For each agglomeration test lOOgr. of the sample and 900 ml. tap water was placed in a 1000 ml. Denver Cell. Then, 35% fuel oil /kerosene emulsion [emulsion% = wt. of emulsion xlOO/ feed wt.x(100-%ash)/100] was added. 0.5 ml. of Na_2SiO_3 (10%) and a few drops of pine oil were added to depress siliceous and pyrite minerals and to improve the frothing. The results obtained for the agglo-flotation are shown in Table 2.

-0.5 mm sized Sorgun/Yozgat lignite fraction was directly fed to the flotation cell. I ml. of NajSiO.i (10%) and 6 ml. of pine oil/kerosene (IV/5V) emulsion were added to the pulp containing 10% solids. After obtaining the concentrate cleaned it was dcwatered and analyzed (Figure 2). The results are shown in Tables 2, and 3.

2.2.2 *The aerial oxidation and ammoniation*

Oxidation experiments were conducted on the cleaned samples. In each case, about 100 gr. of the sample was spreaded on the tlat bottom of an aluminum pan that has 200 mm diameter to provide air lo the particle surfaces completely, and placed in an oven. After heating the sample in atmospheric conditions at 90"C for the periods from 48 to 192 hours, it was cooled.

Then certain amount of oxidized sample was placed in an autoclave and predetermined amount of ammonium hydroxide solution (NHi(g)/coal (g): 0.2 and solid (g)/liquid (g): 1.3-1.7) was added. The mixture was stirred at 90"C tor about one hour. Alter this period, it was observed that it was in muddy form and dark brown colored ammonium humate generated and covered the whole surfaces of the particles. This muddy mixture was taken out of the vessel and dried until to reach 10.50% moisture content.

2.2.3 Briqitetting

In the pressing experiments, 30 g. of the sample obtained from the ammoniation treatment was transferred to a cylindrical steel mould (Figure 3). The sample in the mould was heated up to 80"C externally and pressed between the bottom and top steel discs by the steel pressing piston to which an adjusted pressure was provided from an oil-hydraulic type press. The briquetting pressure was changed from 460 to 1565 kg/cm". After the pressing, the briquette sample was taken out of the mould and placed in a drying oven already heated to 80" C. Heating temperature was then increased from 135 to 175" C for 60 minutes to see the effects of heat treatment or on the strength and moisture resistance properly of the briquettes cylindrical in shape. After this period it was gradually cooled to room temperature and conserved for the analyses and quality tests. The results are shown in Tables 4, 5,6 and7.

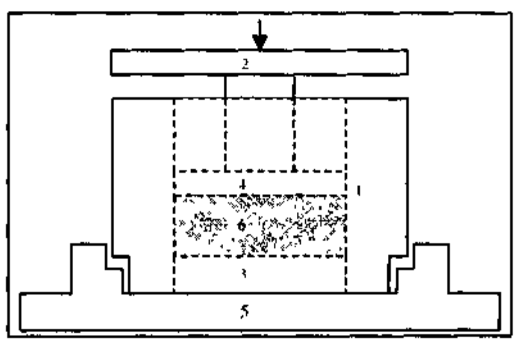

Figure .3 Schematic view of the pressing mould.

1 Sieel mould (46x65 mm)
2. Steel pressing piston (40x 100 mm)
3 Sleel disc-bottom (15-45 mm)
4 Sleel disc-top (15x45 mm)
5. Sleel clown plate (stable)
6 Sample placed

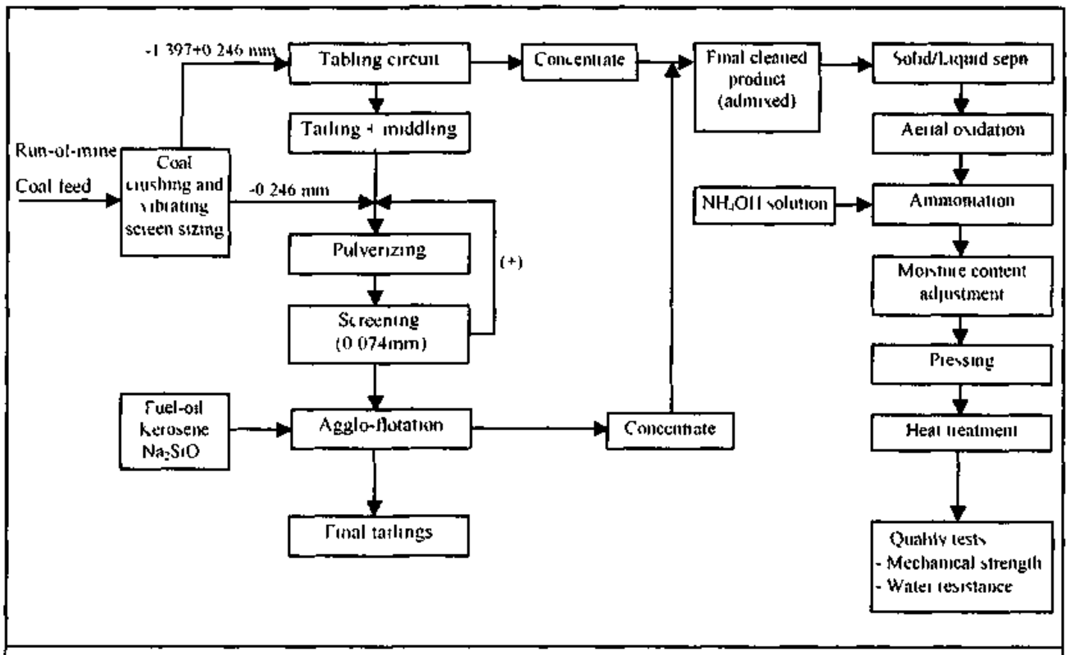

Figure 1. Simplified schematic diagram of the experimental works for the Afsin/Elbistan lignite at laboratory scale

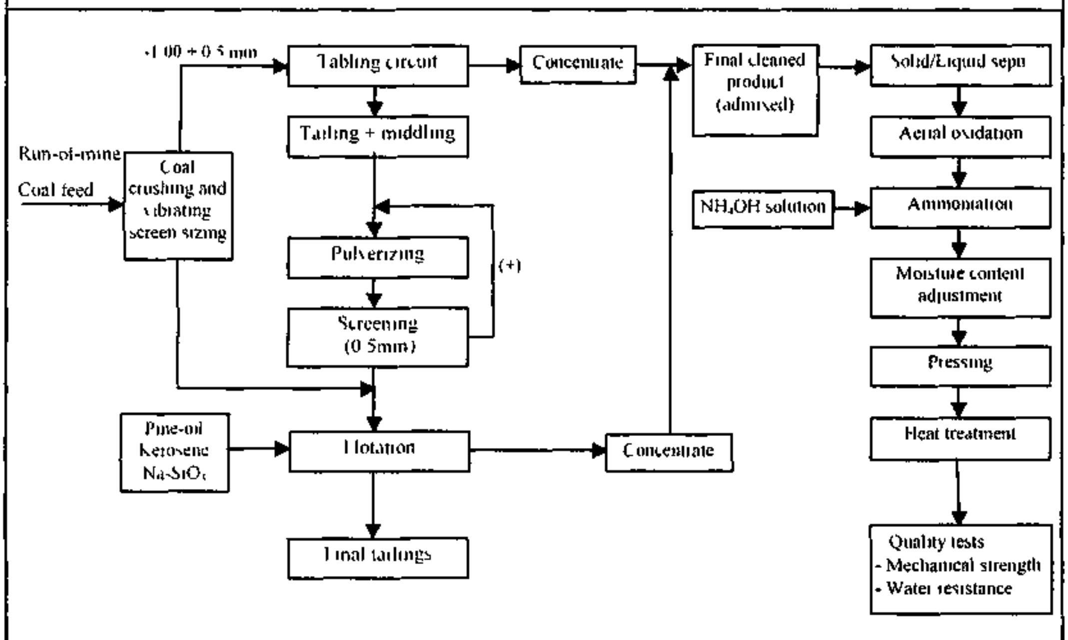

Figure 2. Simplified schematic diagram of the experimental works for the Sorgun/Yozgat lignite at laboratory scale

2.2.4 *Quality tests*

In order to determine the axial-compressive strength obtained by applying compression through the flat surfaces of the tablet like briquettes.an ELE 3000KN compression-testing device was used. After placing the briquettes on the compression unit of the device, pressure was applied through the surfaces and the load required to crush the briquette under compression was recorded. This load was divided by the area of the flat surfaces of the briquettes (15.89 cm") and the axial strength was obtained as kg/cm^{2}.

There has been no standard leading method to measure the water resistance of the coal briquettes. In this work, 5 of the briquettes that each has about 40 cm' volume were immersed in 600 ml of water for 24 hours and after that period the briquettes were dried and screened with a 10 mm sieve. The weight percent of the fines passed through the sieve was found as the water disintegration index. Water resistance of the briquette was calculated by subtracting the water disintegration index from 100.

3 RESULTS AND DISCUSSION

3.1 Cleaning

Table 2. Results of the cleaning operations on the Afsin/Elbistan lignite.

Cleaning Operation	Concent rate Wt. (%)	Ash (%)	Tailing+ middling Wt.	Ash	AR	RC (%)
Tabling	58.1	27.1	41.9	56.4	60.0	69.9
Agglo-flotation	65.4	32.4	34.6	74.6	54.9	83.4

Table 3. Results of the cleaning operations on the Sorgun/Yozgat lignite

Cleaning Operation	Concentrate Wt. (%)	Ash (%)	Tailing+middling Wt. (%)	Ash (%)	AR (%)	RC (%)
Tabling	58.0	15.0	42.0	47.1	69.5	68.9
Agglo-flotation	58.7	14.6	41.3	48.7	70.1	70.3

Percentage of ash rejection (AR) and percentage of recovery of combustibles (RC) were calculated by the following approach, e.g. AR for the tailing and RC for the concentrate (Suresh and Arnold, 1995).

AR(%) = [tails wt. x % ash of tails]x100 /
[tails wt x % ash of tails) + (cone wt x % ash of cone.)]

RC(%) = [cone. wt. x (100 - %ash of cone.)] x 100 /
[conc.wt.x (100- %ash of cone.) + (tails wt.x (100- %ash of tails)]

As shown in Table 2, the ash content was reduced from 39.4% to 27.1% by the tabling circuit and at the end a final product containing 32.4% ash was obtained. It is indicated from these results that liberated inorganic mineral particles that have higher specific gravities than the lignite particles were successfully separated due to the gravity differences. Nevertheless, fairly high percentage of recovery of combustibles (RC) was achieved. The percentage of ash rejection (AR) obtained was not high for the flotation circuit. This was possibly due to the insufficient liberation of clay type mineral matter in the Elbistan lignite. On the other hand it is shown from Table 3, that a clean product containing 14.6% ash was obtained by the flotation, which was the final stage in the cleaning operation of the Sorgun/Yozgat lignite. Hence, the AR and RC values reached were high enough and a low ash-bearing product was obtained.

3.2 Effects of the heat treatment

Table 4. Effect of the heat treatment on the durability of the briquettes (briquetting pressure: 1280 kg/cm^{2}; the oxidation period: 144 hours).

Heat (°C)	Elbistan Lignite Axial Comp. Str. (kg/cm^{2})	Water Resistance (%)	Sorgun Lignite Axial Comp. Str. (kg/cm^{2})	Water Resistance (%)
135	117.7	0	104.0	0
145	12X.1	0	118.1	0
155	133.4	0	126.4	0
165	176.5	0	151.0	100
175	152.3	0	138.2	100

Heat treatment temperature to improve the water resistance of the briquettes was the most critical parameter. The best results for both of the samples were obtained at the temperature 165°C. This result was in agreement with the results obtained by the previous workers (Driskell, 1961; Wen, 1980). The possible reactions took place during the heating operation on the ammonium humate binder could be given as:

$$R\text{-}COONH_4 \longrightarrow R\text{-}CONH_2 + H_2O$$
$$R\text{-}CONH_2 \longrightarrow R\text{-}COOH + R - CN + NH_3$$
$$R\text{-}CN \longrightarrow R\text{-}COOH + NH_3$$
$$R\text{-}COOH \longrightarrow RH + CO_2$$

(Schwartz.et.al., 1965; Jensen.et.al., 1966; Roberts and Marjorie, 1977).

The results shown in Table 4, mentions that although acceptable level of the axial compressive strength of the briquettes produced from both of the samples was achieved, no water resistant briquet was obtained from the Afsin/Elbistan lignite sample. It was most probably due to the finely dissemination of the clay mineral particles in the sample. Whereas, water resistant and durable briquettes were produced at 165"C temperature from the Sorgun/Yozgat lignite sample.

3.3 Effects of the oxidation period

Table 5. Effect of the oxidation period on the durability of the briquettes (briquetting pressure 1280 kg/cm"; heat treatment temp. 165"C).

	Elbistan Liamte		Sorsun Lianite	
Oxidation Period (hours)	Axial Comp. Str. (kg/cm"!1	Water Resistance (%)	Axial Comp. Str. <kg/cnr)	Water Resistance <%)
48	137 1	0	65.6	0
96	147.0	0	93.1	54
144	173.2	0	154.1	100
192	166.0	0	167.1	100

It is shown in Table 5, that as the oxidation period was increased stronger briquettes were obtained. The possible reason was that amount of the alkali soluble humic acid binder which was basically ammonium humate (R-COONH4) salt increased between the particles to be agglomerated (Yildirim and Ozbayoglu, 1997). In order to obtain durable briquettes from both of the samples it was definitely necessary to prolong the oxidation period up to at least 144 hours.

3.4 Effects of the pressure

Table 6. Effect of the briquetting pressure on the durability of the briquettes (oxidation period: 144 hours; heat treatment temperature: 165"C).

	Elbistan Lianite		Soi 21111 Lianite	
Enqueuing Piessure (ke/cnr)	Axial Comp. Sır. (kg/cm^2)	Water Resistance W	Axial Comp. Str. (ka/cıır)	Water Resistance (%)
460	112.4	0	105.0	84
711	135.5	0	128.4	90
995	148.2	0	137.2	91
1280	171.0	0	161.4	100
1565	184.3	0	180.1	100

Briquetting pressure was effective on the axial compressive strength of the briquettes. As it was increased the strength of the briquettes improved. As it is shown in Table 6, when the pressure was 1280 kg/cm^2 100'% water resistance and 161.4 kg/cm" axial compressive strength were achieved for the Sorgun/Yozgat lignite sample. The pressure was not effective on the water resistance of the Afsin/Elbistan lignite briquettes.

Table 7. Results of proximate, sulphur and calorific value analyses of the briquettes obtained from the cleaned products.

Contents	Elbistan Lignite (% dry basis)	Sorgun Lignite (% dry basis)
Moisture		
Ash	29.8	14.8
Volatile matter	34.1	37.5
Fixed carbon	36.1	47.7
Total sulphur	2.5	1.2
Net calorific value	3688	5880

4 CONCLUSIONS

1. In order to decrease ash content of the Afsin/Elbistan lignite sample to lower levels it should definitely be ground into finer size intervals, and an ash removal technique that is efficient in processing finely sized lignite particles such as column dotation may be chosen. There was not any problem in cleaning of the Sorgun/Yozgat lignite by the shaking table and conventional flotation methods.
2. When Afsin/Elbistan and Sorgun/Yozgat lignites are oxidized in air at 90"C for more than 144 hours, ammonium hydroxide soluble humic acids are formed, and it can be extracted in liquid form at 90"C.
3. When the briquettes are heated at temperatures lower than 165"C poor water resistance property are achieved. If the temperature is higher than 165"C water resistant but weak briquettes will be obtained. So, the heat treatment temperature is critical parameter and it is around I65"C in this method.
4. The ammonia gas (NH3) released during the heat treatment can easily be converted into ammonium hydroxide, which can be recycled and used for the extraction of ammonium humate. This will lower the cost of the method.
5. The briquettes having enough mechanical strength but not water-resistant can be produced from Afsin/Elbistan lignite. This method is promising in producing briquettes from lignites containing more than 15% alkali soluble humic acids in organic base and ash that does not consist mainly of clay type mineral matter liberating at very fine sizes.

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