Australian Journal of Basic and Applied Sciences, 7(4): 56-62, 2013
ISSN 1991-8178

Influence Of Adhesive Type And Particles Size On Compressed Charcoal Briquettes Manufacturing

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Abstract: Charcoal briquettes were produced using three different adhesives (Poly Vinyl Acetate (PVA), local wooden glue (Shrees) and Methyl Cellulose (Paper glue) and three different sizes of charcoal particles (fine, medium and course) and two different pressures (2 and 5 kg) during manufacturing of the briquettes, in order to know the effect of these parameters on water temperature gain, specific gravity and ignition period. Results showed that methyl cellulose was the best in obtaining the highest ignition period compared with the other adhesives, but water temperature gain was approximately the same for all studied adhesives type. Also medium size charcoal particles have the best results in increasing water temperature gain, while fine particles was superior in igniting period character. The results also showed that 5 kg applied pressure during manufacturing have larger values for water temperature gain, specific gravity and igniting period compared with 2 kg pressure. Finally, the best treatment to produce charcoal briquettes with a higher values in water temperature gain and ignition period was by using methyl cellulose adhesive with 5 kg pressure. Generally, using all these three type of adhesives will yield an accepted charcoal briquettes for all studied characters.

Key words: adhesives, charcoal particles size, briquettes.

INTRODUCTION

In the last decade, the need for utilizing energy for human usage was increased which encourage scientists and researchers to find an alternatives to fulfill at least a part of energy shortage. Using wooden or rocky charcoal for human need as energy source is considered as one of important resources specially when it utilized for heating, cooking or for factory energy supply. Due to sharp shortage of wood charcoal primary materials, a new method was established to produce a fragments of compressed charcoal particles called (charcoal briquettes) which manufactured by converting tree branches or residue of carpentry factory or agricultural lignocellulosic waste to charcoal, then converting it into compressed particles charcoal (Briquettes) by adding adhesives and applying pressure (Grover and Mishra, 1996). This kinds of briquettes was dramatically increased for cooking usage in united state which sold quantity reached 880748 Ton during 1997 (Anonymous, 2012). Generally, the small charcoal particles produces from wood or tree residue have more impure than large charcoal particles, due to the presence of some sand, clay or minerals derived from the soil or tree bark (FAO, 1987).

Different kinds of adhesive have been used for briquettes production. But the most traditional one used was starch. Starch can be used from 4-8 % of adhesive weight by mixing it with hot water. Briquettes manufacturing can be performed by drying charcoal particles, screening and separating the small particles size. The large particles can be grounded and screened, this process followed by adding and mixing adhesive. ((From 15 – 20% of charcoal particles weight,)) then compressed stage was followed after filling the mixture in a small casts (moulds). After compression stage, drying of briquettes began at 80˚C, the adhesive will hardened after moisture evaporation which lead to particles cohesion. The resulting briquettes can be used and utilized for heating stoves and cooking as any traditional charcoal. Many kinds of additives can be added to the charcoal briquettes to increase its efficiency and usage, such as chemical compound to increase combustion (e.g. wax, sodium nitrate) or emitting good smell during ignition (e.g. Incense, perfume added to hookah (shisha) smoking briquettes) (FAO, 1987). Grover and Mishra (1996) stated that size and shape of charcoal particles have great influence on specific gravity of resulting briquettes, the best particles size are between 6-8 mm, mixed with 10-20% of grounded and small particles in order to improve the strength, filling and packaging technique of the briquettes. Also, they clarify that moisture content have great influence on charcoal particles adhesion. They stated that in addition to adhesives added to charcoal particles, water work as adhesive material producing thin layer connecting charcoal particles with each other by Van Der Wall's forces. This process will increase connectivity area between the particles. Susgumaran and seshardri (2010) found that 200-250 gm of briquettes is enough to cook food in about 45-60 minutes. Also, they reported that the most important benefits which obtained from briquettes manufacturing compared with the traditional wood charcoal can be summarized as follow:

1- Smokeless: The charcoal briquettes burn without much smoke during ignition and burning.
2- Low ash content: Minimum residual ash formed is less than 5% of the original weight of charcoal.

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3- No big differences in calorific value (6243.58 k cal/kg. wood charcoal gave 6592.52 k cal/kg).

4- Odorless: Contains minimum evaporative substances and cause no contamination when contacting other bodies or trays due to the presence of adhesive.

5- Sparkles: No sparks are produced like traditional wood charcoal.

6- Less crack and better strength: Help burn for a longer time.

The purpose of this study is to 1- find the best charcoal particles size and 2- the best local adhesive and 3- the best pressure applied on the charcoal particles to produce briquettes which can give the highest caloric value in a longest ignition period. This research is the first performed in Iraq. Also, no scientific researches are available on briquettes production.

MATERIAL AND METHODS

The charcoal used in this study was collected from the residue of charcoal segments manufactured at College of Agriculture and Forestr, Mosul University. The collected charcoal composed of different sizes of *Populus euphratica* L. wood. The resultant charcoal of this kind of wood characterized by its quality, lightness and fast ignition compared to other wood charcoal types. These charcoal segments were grounded into smaller sizes by using electrical grounding machine, then screened and separated into 3 different sizes by using 4 screening sieves (Course: 7 mish, 2.411 mm. Medium: 8 mish, 2.36mm. Small: 16 mish, 1.18 mm. fine: 30 mish, 0.59 mm in order to discard particles smaller than 0.59 mm).

Charcoal particles separation was performed by arranging course sieve on the top, the other sieves placed under the top sieve by decreasing opening size (mish) gradually, hence the last bottom sieve has the smallest opening size. Each particles size were placed in plastic bags and stored until testing (figure: 1).

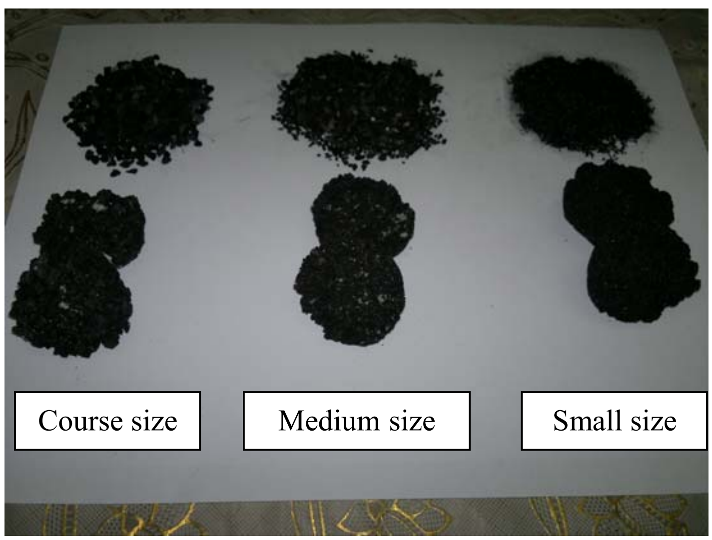

Fig. 1: particles size of charcoal and the manufactured briquettes

Charcoal Briquettes Manufacturing:

Three kinds of cheap adhesives were used: poly Vinyl acetate (PVA). Optalin adhesive made from methylcellulose and shrees adhesive which manufactured locally from the grounded caps of the dried Okra vegetable. The tray which contain 12 molds (figure 2) filled with charcoal particles and the average weight of the three charcoal particles size were 8.466 gm. Optalin adhesive was prepared by mixing 5 gm of adhesive with 142 ml distilled water, shrees adhesive was prepared by mixing 33 gm of adhesive powder with 100 ml distilled water. Each particles size (of 12 mold) were placed in a bowel and mixed with each adhesive at a ratio of 20% of charcoal particles weight. After completion adhesive mixing, a small piece of paper were placed in the bottom of each tray mold to prevent charcoal adhesion with tray metal, then tray molds were filled with charcoal mixture and a piece of paper was placed over each charcoal mold and a cylindrical piece of wood were placed over it (figure 2). Then a piece of known weight ceramic was placed over the 12 wooden pieces and the weight was completed to 2kg by adding sac containing sand over the ceramic. Since the surface area of each wooden piece was 12.57 cm^2, and total area of the 12 pieces was 150.84 ccm^2, the applied pressure of 2 kg was 13.26 gm/cm^2 and for 5 kg the applied pressure was 33.15 gm/cm^2. Each tray containing 12 mold with its applied pressure were inserted into an electric oven on 75 ˚C for 24 hrs for adhesive curing and charcoal particles drying. The resultant briquettes shown in figure (1) were inserted in an incubator at 20 ˚C ±2 and 50% relative humidity for 24 hrs for conditioning before testing. After acclimatization, the samples were stored in plastic bags before being tested.

Fig. 2: Briquettes preparing before pressing

Studied characters:

Water Temperature Gain (WTG):

It is the temperature gained by water from ignition single briquettes. A beaker with 75 ml distilled water were placed over each briquettes. The initial temperature of the water were measured before ignition the briquettes by using digital thermometer. One cup spoon kerosene was added to each briquettes to prepare it for ignition. After kerosene end burning, the beaker was placed on a stand and the briquettes placed under the beaker (Figure 3), a constant speed fan was directed to the briquettes to get constant ignition and the highest temperature of the water was reported during briquettes burning. Water temperature gain was measured by subtracting initial temperature from the highest temperature of the distilled water.

1- **Ignition period:** ignition period was measured by using digital watch from the beginning of briquettes ignition when air fan started until the end of briquettes ignition.

2- **Specific gravity of briquettes:** specific gravity was measured according to Brown et. al. (1952) after sample conditioning by using the following equation:

Specific gravity = density of briquette (gm/cm^2) / water density (gm/cm^2)

Fig. 3: method of measuring water temperature gain and ignition period of the briquettes

Statistical analysis:

factorial Complete Randomized Design (CRD) was used for data analysis including the following factors:

1- Particles size: three levels (fine, medium, course).
2- Adhesive type: three levels (PVA, Shrees, Methyl cellulose).
3- Applied pressure: two levels (2 and 5 kg).

Hence, number of experimental units was 2x3x3=18, and by using 3 replicates, the number of total observation became 54 for each characters. Since WTG and ignition period was measured from the sane samples, and specific gravity was measured from the same samples, and specific gravity was measured with different samples, the total observation became 108. SAS (2002) was used to obtain ANOVA tables (Anonymous 2002), in addition to the significant differences between treatment averages by using Duncan methods (Duncan, 1955). For all studied characters. Time data of ignition period was converted to numbers values for analysis purposes by using the following equation (Anonymous, 2012-a):

(Time 00:00:00 – INT(time))*24

The resultant values from the analysis were converted into time using direct converting system available at the site Anonymous (2012-b).

RESULTS AND DISCUSSION

Table (1) showe ANOVA results which indicate that there were significant difference under 0.01propability level for adhesive type factor in S.G. and ignition period characters, while water temperature gain showed no obvious differences of the same factor. Also the table showe that there were significant differences under 0.01propability level for particles size of all studied characters. While there were significant difference under 0.01propability level for applied pressure factor of water temperature gain and S.G. but it was significant under 0.05 probability level for ignition period. Also table (1) show the interaction effects of the studied factors, there were significant difference under 0.01propability level for adhesive type interaction with particles size, and for adhesive type with applied pressure interaction and for particles size with applied pressure interaction on water temperature gain and ignition period. The effects of the studied factors on S.G. indicated in the table showed that there were significant difference under 0.01propability level for adhesive type with particles size interaction while there were no significant difference for adhesive type with applied pressure interaction on the same character mentioned above. The triple interaction of the studied factors showed that there were significant interaction under 0.05 propability level for water temperature gain and ignition period, but this interaction was not significantly different on SG.

Table 1: ANOVA table shown sum of square means of the studied factors.

Factors	Degree of freedom	Sum of square means		
		WTG	SG	Ignition period
Adhesive type(a)	2	n.s. 3,143	** 0,054	** 0,273
Particles size (b)	2	** 54,763	** 0,0066	** 0,0412
Applied pressure (c)	1	** 40,733	** 0,0116	* 0,0068
axb	4	** 20,451	** 0,0056	** 0,121
axc	2	** 27,476	n.s. 0,0013	** 0,0486
bxc	2	** 22,097	n.s. 0,0005	** 0,0084
axbxc	4	n.s. 10,014	n.s. 0,00104	n.s. 0,0035
Experimental error	36	3,612	0,0007	0,0011

Effect of main factors on studied characters of Duncan analysis for mains:

A- Adhesive type:

Table (2) shows the effect of main factors on studied characters indicating that there were no significantly different between the three adhesives type on water temperature gains, however, PVA adhesive gave the highest water temperature gain of the briquettes (16.950°C) followed by methyl cellulose adhesive (16.794°C) then shrees adhesive (16.161°C). Concerning the effect of adhesive type on SG. It was shown that the highest SG. Was for PVA adhesive (0.377) followed by methyl cellulose adhesive (0.287) then shrees adhesive (0.276). The reason that PVA adhesive gave the highest water temperature gain may refer to increasing of briquettes SG. Compared to the other adhesive type. Hence increasing SG. will increase water temperature gain. Also the effect of adhesive type on ignition period showed that methyl cellulose adhesive was significantly Superior (27 min. and 3 sec.) in ignition period of the briquettes compared with shrees adhesive (14 min. and 34 sec.) or with PVA adhesive (13 min. and 58 sec.). This may refer to the presence of cellulose substances in the methyl cellulose adhesive which may increase ignition period compared to the other studied adhesive.

B- Particles size:

Table (2) shows that medium and small size particle was superior in water temperature gain (17.700 and 17.58°C respectively) compared to course particles size (14.622 °C), and there were no significant differences between medium and small particles for this characters. Briquettes of fine particles was significantly better in SG (0.336) compared to the medium particles (0.304) and course particles (0.301) which showed no significant differences between them. The largest ignition period was for fine charcoal particles (21 min. and 50 sec.) compared to medium particle size (16 min. and 55 sec.) and course particles (16 min. and 54 sec.) which showed no significant differences between them. This may refer to the increasing of SG specially for fine particles due to the minute spaces and pores between charcoal particles of the briquettes, which increase briquettes mass and its SG which affect directly ignition period and water temperature gain compared to course particles size.

C- Applied pressure:

Table (2) for Duncan analysis of means shows that 5 kg applied pressure was superior in increasing water temperature gain (18.041°C) compared to 2kg applied pressure (15.229°C), Also, 5kg applied pressure was better in SG (0.328) and in ignition period (18 min. and 48 sec.) compared to 2kg applied pressure (0.299, 16 min. and 27 sec. respectively). This may refer to the increasing of SG. Due to increasing applied pressure which make the charcoal particles closer to each other leading to increasing of ignition period which by turn increases water temperature gain.

Table 2: Duncan analysis showing the effects of main factors on the means of studied characters of manufactured briquettes.

Factors		Characters		
		WTG(˚C)	SG	Ignition period (min:sec)
Adhesive type	PVA	a 16,950	a 0,377	b 13:58
	Shrees	a 16,161	b 0,276	b 14:34
	Methyl cellulose	a 16,794	b 0,287	a 27:03
Particles size	Fine	a 17,583	b 0,336	a 21:50
	Medium	a 17,700	b 0,304	b 16:55
	Course	b 14,622	a 0,301	b 16:84
Applied pressure	2 kg/cm^2	b 15,229	b 0,299	b 16:27
	5 kg/cm^2	a 18,041	a 0,328	a 18:48

Means with the same letter for each factor are not significantly different at $p \geq 0.05$.

Effect Of Factors Interaction On The Studied Characters:

A - Interaction of adhesive type with particle size: Table (3) indicated the interaction effect of adhesive type with charcoal particle size in water temperature gain and ignition period for PVA adhesive. There were gradual increase in water temperature gain by decreasing particle size (course, medium, fine) (15.900, 16.233, 17.187°C respectively). The reason may refer to the increasing of charcoal briquettes mass and its SG by decreasing particle size leading to increase in water temperature gain. Shrees adhesive showed that the highest water temperature gain was for medium particle size (19.484°C), followed by fine particle size (15.533 °C), while course particle size gave the lowest water temperature gain (13.467 °C), this may refer to the effect of the studied factors interaction with each other. Also, table (3) indicated that ignition period was increased by decreasing particles size (course, medium , fine) for PVA adhesive (11min.and 16 sec.,12 min. and 80 sec.,18 min. and 31sec. respectively), but it was not significant for shrees adhesive (14 min. and 50 sec.,14 min. and 31 sec.,14 min. and 22 sec. respectively). While fine charcoal particles of methyl cellulose adhesive was significantly better in increasing period (32 min. and 42 sec.) compared to medium size particles (24 min. and 11sec.) and to course size particles (24 min. and 22 sec.) which showed no significant differences between them. These results may be referred to the same reasons mentioned in the effect of main factors of adhesive type and charcoal particles size on the studied characters. The lowest ignition period was shown in PVA adhesive for course size particles (11 min. and 16 sec.).

Table 3: Effect of adhesive type with particles size interaction in water temperature gain and ignition period.

Factors		Characters	
Adhesive type	Particles size	WTG(˚C)	Ignition period (min:sec)
PVA	Fine	a b 18,717	c 18:31
	Medium	a-d 16,233	d 12:80
	Course	b-d 15,900	d 11:16
Shrees	Fine	b-d 15,533	c d 14:22
	Medium	a 19,483	c d 14:31
	Course	d 13,467	c d 14:50
Methyl cellulose	Fine	a b 18,500	a 32:42
	Medium	a-c 17,383	b 24:11
	Course	d c 14,500	b 24:22

Means with the same letter for each column are not significantly different at $p \geq 0.05$.

B - Interaction of adhesive type with applied pressure: Table (4) indicated that water temperature gain for 5kg applied pressure for PVA adhesive (18.678°C) was better than 2kg applied pressure (16.333°C), the same results for shrees adhesive (16.356, 15.967°C respectively) but there were no significant differences between them, and for methyl cellulose adhesive (19.089, 14.500°C respectively). These results may be referred to the same reasons mentioned in the effect of main factor of applied pressure in water temperature gain. Knowing that the highest water temperature gain was when using methyl cellulose adhesive at 5 kg applied pressure (19.089°C) and the lowest was at 2kg of the same adhesive mentioned above (14.500°C). On the other hand the interaction effect of adhesive type with applied pressure in ignition period shown in the table indicated that ignition period of 5 kg applied pressure for PVA adhesive (14 min. and 45 sec.) was slightly higher from 2 kg applied pressure (13 min. and 11 sec.) but there were no significant between them. However these differences become significant when using methyl cellulose adhesive (30 min. and 49 sec., 23 min. and 21 sec. respectively) and for shrees adhesive (17 min. and 40 sec., and 12 min. and 50 sec. respectively). The reason may refer to a closer aggregate of charcoal particles due to strong adhesive cohesion of methyl cellulose and shrees adhesives. This lead to minimizing oxygen present between charcoal particles compared with 2 kg applied pressure, hence ignition period increased. The highest ignition period was for methyl cellulose at 5 kg applied pressure (30 min. and 49 sec.) and the lowest was for shrees adhesive 2 kg applied pressure (12 min. and 50 sec.).

Table 4: The effect of adhesive type with applied pressure interaction in water temperature gain and ignition period.

Factors		Characters	
Adhesive type	Applied pressure (kg/cm^2)	WTG(°C)	Ignition period (min:sec)
PVA	2	a b 16,333	c d 13:11
	5	a 18,678	c d 14:45
Shrees	2	a b 15,967	c 12:50
	5	a b 16,356	d 17:40
Methyl cellulose	2	b 14,500	b 23:21
	5	a 19,089	a 30:49

Means with the same letter for each column are not significantly different at $p \geq 0.05$

C- Interaction of charcoal particles size with applied pressure: Duncan Table (5) for means shows that 5 kg applied pressure for fine and medium particles size was significantly better in water temperature gain adhesive (19.022 and 19.733°C respectively) compared to 2 kg applied pressure (16.144 and 15.667 respectively). This results may refer to the same reasons mentioned in the effect of applied pressure as main factor on water temperature gain. The table also showed that water temperature gain of 5kg applied pressure for course particles (15.367°C) was better than 2 kg applied pressure (13.878°C) but with no significant differences between them, knowing that the highest water temperature gain was at 5 kg applied pressure for medium particles size (19.733°C) and the lowest was at 2 kg for course particles (13.878°C). Also table (5) shows that ignition period for 5 kg applied pressure of medium particles size was higher compared to 2 kg applied pressure (17 min. and 52 sec., 16 min. and 20 sec. respectively), the same results was shown for fin particles size but they were not significant (23 min. and 42 sec., 20 min. and 10 sec. respectively). These results may be refer to the same reasons mentioned in the effect of main factors of applied pressure in ignition period. Course particles size showed there were significant increase in ignition period for 2 kg applied pressure (17 min. and 34 sec.) compared to 5 kg applied pressure (16 min. and 50 sec.). The reason may refer to the increasing of spaces and pores between course charcoal particles of 2 kg applied pressure compared to 5 kg applied pressure, which delay the ignition of course charcoal particles leading to increasing of ignition period.

Table 5: Interaction effect of charcoal particles size with applied pressure in water temperature gain and ignition period.

Factors		Characters	
Particles size	Applied pressure (kg/cm^2)	WTG(°C)	Ignition period (min:sec)
Fine	2	b 16,144	a 20:10
	5	a 19,022	a 23:42
Medium	2	b 15,667	b 16:20
	5	a 19,733	a 17:52
Course	2	b 13,878	a 17:34
	5	b 15,367	b 16:50

Means with the same letter for each column are not significantly different at $p \geq 0.05$

Conclusion:

it was possible to manufacture compressed charcoal particles (briquettes) with acceptable characteristic (water temperature gain and ignition period) by using poly vinyl acetate (PVA) or local wood glue (shrees) or methyl cellulose (paper glue). There were some differences between adhesive type and applied factor (particles size and applied pressure). Methyl cellulose adhesive is the best which can higher ignition period compared to the other adhesives, Also the water temperature gain for the adhesive is really equal to the other used adhesives. Using medium charcoal particles size is better in increasing water temperature gain, Also fine particles size is superior in increasing ignition period, While course particles increase specific gravity for the manufactured briquettes. Using 5 kg applied pressure give better water temperature gain and specific gravity and ignition period compared to 2 kg applied pressure. Generally we can concluded that using methyl cellulose adhesive at 5 kg applied pressure and fine particles size will gave the best result in water temperature gain and ignition period.

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