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Effect of Biomass Type and Proportion of Binding Material on Strength and Burning Quality of Honey-Comb Briquette

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ABSTRACT

Experiments were conducted to characterize the briquetting technology for better utilization of agricultural, forestry and municipal wastes. Honey-comb briquettes were made by using char produced from three different biomasses (i) Rice husk (ii) Banmara and (iii) Paper with two different binding materials *viz.* clay and cow dung (20%, 30%, 40% and 50% by weight) and was tested for strength, durability and combustion properties. The result indicated that compressive strength increased with increase in proportion of binding material. The calorific value was found to be highest i.e. 5656.58kcal/kg and lowest i.e. 3602.99 kcal/kg for BG_{50} and RC_{50}, respectively. Calorific value of briquette was decreased with increase in proportion of binding materials in case of clay whereas calorific value increased with increase in proportion of binding materials in case of cow dung. The highest value of total burning time was 110 min. for RC_{30} whereas lowest value of total burning time was 79 min. for PG_{50}. The highest value of effective cooking time was 79 min. for RC_{30} whereas lowest effective cooking time was 55 min. for PG_{50}. Briquette having 30% level of binding material was found to be best suited for briquette production with respect to calorific value and effective cooking time.

Introduction

Many of the developing countries produce huge quantity of agricultural residues but they are used inefficiently causing extensive pollution to the environment i.e. agricultural wastes are excess of agricultural production that have not been effectively utilized. With the remarkable increase in agricultural production, the availability of different types of agricultural by products, wastes and residues has also increased. These include crop residues, processing by products, animal refuse and forest biomass. It is estimated that a huge amount of such products are annually produced in Nepal in the form of straw, stalks, husk, cobs, shells, sticks and peel etc. (Shrestha, 2003). But bulk of such materials remains unutilized and their disposal becomes a problem. This happens due to their scattered and seasonal availability, bulky nature, low density and physico-chemical characteristics (Singh and Sahay, 2002). Apart from the problems of transportation, storage and handling, the direct burning of loose biomass in conventional grates is associated with very low thermal efficiency and widespread air pollution.

In addition, a large percentage of unburned carbonaceous ash has to be disposed off. In the case of rice husk, this amounts to more than 40% of the feed burnt (Grover and Mishra, 1996). Briquetting of the husk could mitigate these pollution problems. At the same time this can be used as important industrial and domestic energy resource.

Honey-comb briquetting technology

A honey-comb briquette is a solid fuel made out of biomass char. It is so called because its shape resembles like a honey-comb. Dried biomass is made into char by carbonizing in a charring drum.

The charring drum is a simple drum which is fitted with a conical shaped grate, a chimney and water-seal arrangement. About 40-100 kg of dried bio-mass can be carbonized to give 25-35% yield of charcoal material over a period of two to three hours (icimod@icimod.org.np). The biomass char powder is mixed with binding materials (clay, cow dung and so on) along with the required quantity of water. The mixture is filled compactly in the briquetting mould and thus prepared briquettes are dried in the sun for about two to three days and thereafter ready for use.

Experimental design

The variables of the study were: Biomass, binding materials and proportion of binding materials selected as parameters for the preparation of Honeycomb briquettes.

The total number of experiments was divided into three groups on the basis of biomass used for the preparation of briquettes. Each group of experiments was conducted separately to study the briquetting process and quality attributes by using two different binding materials.

The ranges of variables under study were selected on the basis of earlier research work. The four levels of binding material proportion were taken and reported in Table 1. A full factorial design was used to conduct the experiments and to decide interaction effects of variables on the responses. The experimental design is given in Table 2 and the plan consisted of 8 experiments in each group with three replications.

The total number of experiments decided in this way was found to be 72 (=24x3 replications).

Quality Analysis

The briquettes obtained from the different experimental runs were tested for

Compaction (Bulk density)

Compressive strength

Calorific value

Total Burning time

Effective cooking time

Ash content

Effect of variables on bulk density

The variation of bulk density was varied in the range of 0.257 to 0.510 g/cm3 for entire period of experiments. Highest bulk density was observed in BC50 whereas lowest bulk density was found in case of PG20.

From the above data it was found that, the value of bulk density was increased with increase in proportion of binding material. High proportion of binding material indicated more compacted nature of briquette and vice-versa. As the bulk density is directly proportional to weight of the briquette, more compacted briquette had more weight and hence resulted higher value of bulk density.

The analysis of variance for the data of bulk density given in Table 3 shows that biomass, binding material and proportion of binding material have significant effect on bulk density at 1% level of significance. The interaction of biomass and binding materials has also significant effect on bulk density at 1% level of significance where as interaction of biomass and proportion of binding materials as well as interaction of binding materials and proportion of binding material have no significant effect on bulk density at 5% level of significance.

Effects of variables on compressive strength

The value of compressive strength was varied in the range of 0.0338 to 0.3380 N/mm2. The highest value of compressive strength was related to BC50 whereas the lowest was related to PG20.

The data revealed that compressive strength of briquette increased with increase in proportion of binding material i.e. higher the value of proportion of binding material, higher will be the compressive strength and vice-versa. High proportion of binding material made more compacted nature of briquette and hence resulted into high value of compressive strength.

The briquettes made from clay as binding material had higher compressive strength as compared to cow dung for the same level during entire range of experiments. This resulted because of the more adhesive nature of clay over cow dung.

The analysis of variance given in the Table 4 shows that biomass, binding materials and proportion of binding materials have significant effect on compressive strength at 1% level of significance. Similarly, the interaction of biomass and binding materials as well as binding materials and proportion of binding materials has significant effect on compressive strength at 5% level of significance. Whereas interaction of biomass and proportion of binding material has non-significant effect at 5% level of significance.

Effect on variables on calorific value

The variation of calorific value was found to be in the range of 3602.99 to 5656.58 kcal/kg. Highest calorific value was related to BG50 whereas lowest value was related to RC50.

It was found that calorific value goes on decreasing (in case of clay as binding material) as proportion of binding material increased. Calorific value goes on increasing with increase in binding material proportion (in case of cow dung as binding material) during entire range of experiments. As cow dung itself has burning property, briquettes made from cow dung as binding material had greater calorific value over the briquette made from clay as binding material.

The analysis of variance as shown in Table 5 revealed that biomass and binding material have significant effect on calorific value at 1%

level of significance whereas the proportion of binding material has non- significant effect at 5% level of significance. The interaction of biomass and binding material as well as binding material and its proportion have also significantly effect on calorific value at 1% level of significance where as interaction of biomass and proportion of binding material have no significant effect on calorific value at 5% level of significance.

Effect of variables on total burning time

The variation of total burning time was varied in the range of 79 min to 110 min. in the entire range of experiments. Highest total burning time was related to RC30 whereas the lowest total burning time was related to PG50.

The analysis of variance for the data of total burning time shown in Table 6 revealed that biomass, binding material and proportion of binding material have significant effect on total burning time at 1% level of significance of significance whereas, the rest interactive parameters have non-significant effect at 5% level of significance.

Effects of variables on effective cooking time

The value of effective cooking time was varied in the range of 55 min to 80 min for PC50 and PC30 respectively. It was found that the value of effective cooking time goes on increasing to a certain level of binding material (up to 30%) and then started to decrease. It was also found that the briquettes made from clay as binding materials has higher effective cooking time as compared to cow dung for the same level.

The analysis of variance for the data of effective cooking time given in the Table 7 shows that biomass and proportion of binding materials have significant effect on effective cooking time at 1% level of significance where as the binding materials has no significant effect on effective cooking time at 1% level of significance. Similarly, the interactions of biomass and binding materials have significant effect on effective cooking time at 5% level of significance whereas rest interactive parameters have non-significant effect at 5% level of significance.

Effects of variables on ash content

The highest value of ash content was observed as 49 % for RC50 and lowest value was observed as 18 % for BG50.

The effect of percent binding material on ash content for Banmara, Rice husk and paper respectively shows that the value of ash content goes on increasing with increase in proportion of binding material in the case of clay, where as the value goes on decreasing with increase in proportion of binding material in case of cow dung.

The analysis of variance for the data of ash content shown in the Table 8 revealed that biomass and binding materials have significant effect on ash content at 1% level of significance whereas the proportion of binding materials has no significant effect on ash content at 1% level of significance. Similarly, the interactions of biomass and binding materials as well as proportion of binding material have significant effect on ash content at 1% level of significance. Where as rest interactive parameter has non-significant effect at 5% level of significance.

The briquettes obtained from different pre-determined conditions were tested for strength, durability and combustion properties successively in order to optimize and characterize them for economic and better utilization of agricultural forestry and municipal wastes. The quality was judged on the basis of bulk density, compressive strength, total burning time, effective cooking time, calorific value and ash content.

For the strength and durability of briquette, measurement of bulk density and compressive strength was carried out where as for combustion properties, total burning time, effective cooking time, calorific value and ash content were evaluated. The test of significance was conducted for different variables of the study in the form of ANOVA. The conclusions of the study were as follows:
Charring of 28 kg rice husk, about 30 kg banmara and 30 kg paper was converted into 9, 12 and 10 kg charcoal respectively i.e. 32 to 40 % of charcoal was obtained during entire period of experiments. The charring time for above-mentioned quantity of raw materials was 60, 80 and 75 minutes respectively.

From mixture of 1 kg charcoal and binding materials, the numbers of briquettes obtained was varied from 3 to 4.

Briquette having 30 % level of binding material was found to be best suited for briquette production with respect to calorific value and effective cooking time.

On the basis of experiences gained following recommendations are prescribed:

Improvement in design of charring drum should be essential in order to make it suitable for charring of very dense biomasses like sawdust. Manual grinding of charcoal and mixing of grinded charcoal with binding material is unhygienic works. Although using of mask stands to be one of the preventive measures, however, there should be provision of proper grinder and mixer.

The number of holes in the Briquetting mould can be changed which may be helpful for analyzing different characteristics of briquettes like compressive strength, effective cooking time and so on.

Proper advertisement and promotion of this technology is strongly recommended as it is the best method for utilization of agricultural and forestry wastes.

This technology helps in the upliftment of the living standard of the people in rural areas, which is most dominant in developing countries like Nepal. Hence, this technology should be focused in rural areas.

Government and Non-governmental agencies working in environmental sector should also pay their attention towards this technology. Proper attention in time helps minimize environmental and ecological consequences.

Table.1 Process variables and their levels

Process Variables	Level			
Biomass	Rice husk	Banmara (local Shrub)	Paper	
Binding Materials	Clay		Cow-dung	
Proportion of binding materials (%)	20	30	40	50

Table.2 Experimental design deciding the combination of variable in order to conduct the experiments

Expt. No.	Bio-mass	Binding Materials	Proportion of B.M.	Abbreviations
1.	Rice Husk	Clay	20	RC20
2.			30	RC30
3.			40	RC40
4.			50	RC50
5.		Cow Dung	20	RG20
6.			30	RG30
7.			40	RG40
8.			50	RG50
9.	Banmara (local Shrub)	Clay	20	BC20
10.			30	BC30
11.			40	BC40
12.			50	BC50
13.		Cow Dung	20	BG20
14.			30	BG30
15.			40	BG40
16.			50	BG50
17.	Paper	Clay	20	PC20
18.			30	PC30
19.			40	PC40
20.			50	PC50
21.		Cow Dung	20	PG20
22.			30	PG30
23.			40	PG40
24.			50	PG50

Table.3 Analysis of variance for Bulk density

Source	DF	SS	MS	F	P
A	2	0.018130	0.009065	41.80	0.000
B	1	0.056212	0.056212	259.20	0.000
C	3	0.016683	0.005561	25.64	0.001
A x B	2	0.009005	0.004502	20.76	0.002
A x C	6	0.005429	0.000905	4.17	0.053
B x C	3	0.001655	0.000552	2.54	0.152
Error	6	0.001301	0.000217		
Total	23	0.108413	0.004714		

A = Biomass
B = Binding material
C = Proportion of binding material

Table.4 Analysis of variance for Compressive strength

Source	DF	SS	MS	F	P
A	2	0.038166	0.019083	78.92	0.000
B	1	0.020606	0.020606	85.21	0.000
C	3	0.043152	0.014384	59.48	0.000
A x B	2	0.002683	0.001342	5.55	0.043
A x C	6	0.003253	0.000542	2.24	0.174
B x C	3	0.004858	0.001619	6.70	0.024
Error	6	0.001451	0.00242		
Total	23	0.114169	0.004964		

A = Biomass
B = Binding material
C = Proportion of binding material

Table.5 Analysis of variance for Calorific value

Source	DF	SS	MS	F	P
A	2	5874112	2937056	159.78	0.000
B	1	1200249	1200249	65.30	0.000
C	3	43325	14442	0.79	0.544
A x B	2	142726	71363	3.88	0.083
A x C	6	100793	16799	0.91	0.542
B x C	3	459066	153022	8.32	0.015
Error	6	110291	18382		
Total	23	7930563	344807		

A = Biomass
B = Binding material
C = Proportion of binding material

Table.6 Analysis of variance for total burning time

Source	DF	SS	MS	F	P
A	2	1149.75	574.875	82.62	0.000
B	1	121.50	121.50	17.46	0.006
C	3	72.33	24.111	3.47	0.091
A x B	2	12.25	6.125	0.88	0.462
A x C	6	20.92	3.486	0.50	0.789
B x C	3	5.50	1.833	0.26	0.850
Error	6	41.75	6.958		
Total	23	1424.00	61.913		

A = Biomass
B = Binding material
C = Proportion of binding material

Table.7 Analysis of variance for effective cooking time

Source	DF	SS	MS	F	P
A	2	1369.33	684.667	385.13	0.000
B	1	6.00	6.000	3.37	0.116
C	3	103.50	34.500	19.41	0.002
A x B	2	36.00	18.00	10.12	0.012
A x C	6	12.00	2.000	1.12	0.445
B x C	3	6.33	2.111	1.19	0.391
Error	6	10.63	1.778		
Total	23	1543.83	67.123		

A = Biomass
B = Binding material
C = Proportion of binding material

Table.8 Analysis of variance for Ash content

Source	DF	SS	MS	F	P
A	2	30071.1	15035.5	250.42	0.000
B	1	18816.0	18816.0	313.38	0.000
C	3	710.0	236.7	3.94	0.072
A x B	2	6889.8	3444.9	57.37	0.000
A x C	6	782.3	130.4	2.17	0.184
B x C	3	5524.0	1841.3	30.67	0.000
Error	6	360.3	60.0		
Total	23	63153.3	67.123		

A = Biomass
B = Binding material
C = Proportion of binding material

This eco-friendly technology minimizes the health hazards prevailing in the people working most of the time in rural traditional kitchens. Hence, those organizations working under health of rural people should focus their program on this technology.

It needs a cooperation and coordination between government agencies, NGOs, Educational and Research institutions and rural people for optimum utilization of various kinds of wastes.

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