Waste to Energy Conversion through Briquetting in Lac Industry in India

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Abstract— The wastes are thrown to the land and causes land pollution. The waste can be made into briquette and can be used as household fuel by the villagers. The villagers have to struggle while cooking with the woods as a fuel. The main drawback of the wood as fuel is that it produces too much smoke which causes cough and become asthmatic. Wood as a fuel gives 3500 kcal/kg as calorific value. Briquette is a dried organic matter mainly dried leaves or sticks, bound with dung. A briquette can give calorific value up to 3800-6000 kcal/kg which is more than wood. It also produces lesser smoke. Coal or charcoal can give more calories than wood. Besides being expensive it is a non-renewable resource which is depleting. Wood is obtained from trees so increases deforestation. Briquetting is an innovative technology that can solve problem of land pollution as well as depletion of non-renewable resources. Being organic, the waste can also be used biologically. But main problem with the waste used for briquetting is that it contains traces of sodium ions as soda ash (Na2CO3) and sodium hypo chloride (NaOCl2) which may increase soil alkalinity.

Key words: Briquetting, Lac, GCV, Kirri, energy conversion

I. INTRODUCTION

Industrial effluent has toxicity as well as utility. Both the term can be justified. If remained untreated it can be hazardous or if it is treated with chemicals it detains its property and cannot be further reused or recycled. If treated efficiently, Utility of the effluent can reduce the demand of non-renewable resources of energies like coal. Non renewable fuel affects the environment in several ways. Not only is the resource depleting but it also adds as a major pollutant. These are just the environmental effects, for the developing economies like India; socio-economic effect is another side of the coin. The effluent can be conventional as well as renewable source of energy with cost-effective and environment friendly nature. It is nothing but the Biomass Conversion to energy. Briquetting is the process of conversion of biomass of low bulk density in a concentrated form of energy in the form of solid fuel.[1] Many studies has been carried out to understand the use of briquettes as energy sources in which many studies have compared the economical-environmental effect of briquettes as a substitute of conventional fuels. In these studies a cost effective option has been taken as means to reduce the CO and CO_2.[2,3,4,5,6,7] Many scientists worked out the analysis of the demand, political support and promotion mechanism for the briquette's ability to being the substitute of traditional fuel in markets of different European, American and Asian countries.[8,9,10,11,12] The chief advantages of briquettes are higher energy content, lower cost of transportation and storage, uniform quality of product like constant humidity and higher mass fluency.[13,14] Consumption of briquettes in rural areas has given better economic performance over the other traditional fuel like firewood and charcoal.[15,16] Biomass is of great importance due to its easy finding, low price, and very high potential. Several types of biomass can be used for briquetting like agricultural waste, forest residues, industrial and municipal waste and refuse derived fuel. [1]

A. *About the Industry:*

Tajna river industries pvt. Ltd (TRIPL) is a medium scale industry running with the collaboration of kane International Corporation. TRIPL is situated near the banks of river Tajna, Khunti, district-Ranchi, Jharkhand. Khunti is a small town which is rich in LAC tree and lac producing insect (lac-insect) Kerria lacca. Tajna river industries pvt. Ltd (TRIPL) has two sections-TSPL and Bleaching plant. TSPL (Tajna Shellec Private Limited) performs main function for both the plant. Inside TSPL raw materials from the tree is collected in the godown (store room). The trees used for lac insect (Kerria lacca) to produce lac are mainly divided according to the seasons, mainly winter and summer. Lac is the salivary protective coating secreted by lac insect Kerria lacca as it moves along the branches of the tree. The wood from the trees respective to their season, which is coated with lac, is collected.

B. *Trees for Cultivation:*

Name of Tree	Botanical name	Season for cultivating
Kusum or kusumi	Schleichera oleosa	Winter
Ber or baisakhi	Ziziphus mauritiana	Summer
Dhak or palash	Butea monosperma	spring or autumn

Table 1: Name of trees and their botanical name and season for cultivation

C. *Bleaching Plant:*

The collaborator demands for the colorless, unpigmented or bleached shellac for its use. Hence bleaching is required.

D. *Processes Summary:*

Shellac is either golden yellow or reddish brown in color, often referred as seedlac as a raw materials for the processing in bleaching plant.

1) First of all, Seedlac is dissolved in 98% soda ash (Na_2CO_3) at 80ºC in the dissolving tank having impellers. The retention time for the reaction is one hour.

2) Now the solution is filtered using 60 size (0.60 mm) cloth. The filtered solution (filtrate) is called red solution.
3) The residue (insoluble seedlac) is thrown as waste which is known as kirri.
4) Percentage concentration of red solution is measured using refractrometer. It is made to 14% by adding tap water.
5) 14% red solution is then bleached with the 4% sodium hypochloride ($NaOCl_2$) in the bleaching tank. (Concentration of $NaOCl_2$ should not exceed 4%).
6) Then the solution is cooled at heat exchange equipment. The temperature is brought to 14ºC-15ºC.
7) The cooled solution is then filtered using cloth size 60. The filtrate is processed for finishing as bleached shellac. The residue is reprocessed to make wax (by products).
8) The residue is dried. Added tap water and sodium carbonate i.e. soda ash (Na_2CO_3) and heated at 100ºC for two hours.
9) After two hours, liquid solution is poured into bucket and wax is formed within 24 hrs. This is impure wax.
10) Moisture is removed through drying. Cut into pieces. Heated at 100ºC, and sieved. Pure wax is obtained within five minutes.
11) The residue is again reprocessed.
12) Pure wax product is the by product and sold to different customers.

E. Wastes/Effluent and Environment:

Waste or the effluent from the industry can be classified into two categories- processing waste and industrial waste. The industrial waste is the kirri i.e. insoluble shellac (dirt) from the bleaching plant. The waste being derivative of resin (lac) is originally organic in nature. But during processes and treatment it is being traced with the chemicals like $NaOCl_2$, soda ash, and HCl which might have undergone slight changes during the reaction. Processing waste comprises of separated sticks in the form of husks. It retains it property. But the traces of the same chemicals have been found which can be removed through washing. Along with these waste, sewage – the waste water is also released in the form of effluent. The sewage is acidic in nature of pH 2.5. To neutralize it, 98% of soda ash is used, which is expensive. Environment department from the Jharkhand commits that these effluent comprises of highly dosed chemicals. If released in the river, they will cause water pollution. And if left exposed in the field causes land pollution in form of soil toxicity.

II. METHODOLOGY

1) Four sets of mixture were prepared according to the dung content named as A, B, C and D.
2) In every type several combinations were prepared with definite proportion of kirri, dung and agricultural waste like husk, dried leaves and sticks.
3) Ash content, moisture content and Gross Calorific Values (GCV) were calculated according to equation-

GCV (MJ/kg) = 1.1- (ash content + moisture content)

A. Preparation of Briquette:

1) Briquette is the compact biomass containing dung as binding material and agricultural waste like dried leaves and sticks and definite amount of industrial waste i.e. kirri and processing waste i.e. husks.
2) A mechanism to churn them is required for that brick molding machine is needed.
3) The mixtures are made up to 500gms according to the given proportion.

B. Moisture Content Analysis:

Moisture content is the key factor in the quality of briquettes. Moisture evaporated at high pressure and temperature and this moisture also partially hydrolyzes lignin, hemicelluloses and cellulose to lower molecular products which acts as adhesive for binding the particles. [18-26] the moisture content of raw biomass was determined by calculating the loss in weight of material using hot air oven dying method at 105℃ to 110℃ for one hour and up to constant weight loss. [27]

1) A definite amount of the sample is taken as w1.
2) Now crucible is weighted as w2.
3) The crucible is heated in an electric hot air oven maintained at 105 ^{0}C-110 ^{0}C for about 6-8 hrs.
4) The moisture of the sample was evaporated; the crucible is taken out, cooled in a desiccators and weighted again.(w3)
5) The weight of moisture is calculated as w2 – w3**.**
6) % moisture = (weight of moisture/weight of sample) ×100

C. Ash Content Analysis:

Ash is important factor in deciding the heat transfer to the surface of a fuel and for the diffusion of oxygen to the fuel surface during char combustion. [28] It has been proven that if the ash content of the briquette is high then the calorific value will be low. Higher ash content also causes the higher dust production and affects the volume of combustion and the efficiency of the briquette. [29, 30]

1) The above crucible sample was then heated in electric furnace at 750 ± 50 ^{0}C for three hours.
2) By this time sample would have completely burnt off to get ash content.
3) The crucible is taken out after the complete burning and cooled in the desiccators and the weight of the left over ash is determined.
4) % ash content**=** (weight of ash/weight of sample) ×100

D. Gross Calorific value (GCV):

GCV is given by:-

GCV (MJ/kg) = 1.1- (ash content + moisture content)

1.1 is the calorific constant given by CIMFR (Central institute of mining and fuel research, Dhanbad)

$$1MJ = 10^6 J$$

$$1J = 4.18 \text{ calories} = 4.2 \text{ cal}$$

The total energy needed to bring a briquette at its pyrolytic temperature depends upon moisture content which affects the internal temperature due to endothermic evaporation. [31]

E. Observation Table:

Percentage of Dung & name of different combination		Waste Combination (%)	Ash Content (%)	Moisture Content (%)	GCV (kcal/kg)
	A1	1.) 20-k, 20-h, 40-dls	6	10	3948
	A2	2.) 30-k, 30-h, 20-dls	4.9	10	3994.2
	A3	3.) 40- k, 30- h, 10-dls	3.8	8	4124
A 20%	A4	4.) 30-k, 40-h, 10-dls	5	11	3948
	A5	5.) 40-k, 40-h	5.1	10	3985.8
	A6	6.) 50-k, 30-h	2.8	10	4082
	A7	7.) 30-k, 50-h	4.1	4.1	4027.8
	B1	1.) 20-k 20-h, 20 dls	6.1	12	3859
B. 40%	B2	2.) 30-k, 20-h, 10-dls	5.8	12	3872
	B3	3.) 20-k, 30-h, 10-dls	6.0	12	3864
	B4	4.) 30-k, 30-h	5.9	13	3826.2
	B5	5.) 40-k, 20-h	6.2	13	3813
	B6	6.) 20-k, 40-h	6.0	13	3822
	C1	1.) 20-k, 10-h, 10-dls	6.5	14	3759
C. 60%	C2	2.) 10-k, 20-h, 10-dls	6.7	14	3750
	C3	3.) 20-k, 20-h	7.0	12	3822
	C4	4.) 30-k. 10-h	6.8	13	3788
	C5	5.) 10-k, 30-h	6.9	14	3742.2
	D1	1.) 5-k, 5-h, 10-dls	14	15	3402
	D2	2.) 10-k, 5-h, 5-dls	11.1	15	3523
	D3	3.) 5-k, 10-h, 5-dls	11.6	15.5	3481
D. (80%	D4	4.) 10-k, 10-h	11.0	15.6	3502
	D5	5.) 5-k, 15-h	11.8	16	3452.4
	D6	6.) 15-k, 5-h	11.2	16	3477.6

Table 2: Waste combination, content of dung, ash, moisture and GCV of all sets

Where k= Kirri, h= husk and dls= dried leaves and sticks

III. RESULT AND DISCUSSION

Sets	Maximum		Minimum	
	GCV	Combination	GCV	Combination
A	4124	40- k, 30- h, 10-dls	3948	1.) 20-k, 20-h, 40-dls 2.) 30-k, 40-h, 10-dls
B	3872	30-k, 20-h, 10-dls	3813	40-k, 20-h
C	3822	20-k, 20-h	3742.2	10-k, 30-h
D	3523	10-k, 5-h, 5-dls	3402	5-k, 5-h, 10-dls

Table 3: combinations producing maximum and minimum GCV of all sets

1) It is clear from the above table that maximum energy production can be obtained from the combination of 40% Kirri, 30% husk and 10% dried leaves and sticks with the addition of 20% dung. Other higher energy production potentials were shown by combinations like 50% kirri, 30% husk with 20% dung (4082 Kcal/kg) and 30% kirri, 50% husk with 20% dung (4027.8 Kcal/kg).
2) It has been seen that the maximum energy production potential were given by combinations of set A, while minimum energy production potential were given by combination of set D. The sequence of energy production potential is A > B > C > D.

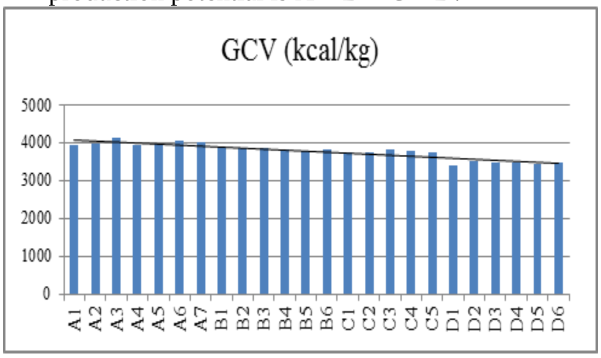

Fig. 1: GCV of all combinations of all sets

3) It has been seen that briquette gives highest calorific value of 4124 kcal/kg and minimum of 3402 kcal/kg. On an average 3786 kcal/kg is attainable from all combination of all the sets, which is more than wood fuel and traditional briquette whose calorific values are 2500 kcal/kg and 3500 kcal/kg respectively. Its calorific value is reaching or even higher than the 'F'

grade coal. ‘F’ grade coal is being used in the industries.

Coal grades	GCV/UHV in kcal/kg
A	7201- above
B	6601-7200
C	5901-6600
D	4201-5900
E	3361-4200
F	2401-3360
G	1301-2400

Table 4: grades of coal and their respective GCV

4) It has been seen from the graph given below (Fig. 2) that there is a negative correlation between GCV and ash and moisture content the correlation coefficient between GCV and ash content is -0.9727 while it is -0.8698 between GCV and moisture content; so that as we increase the percentage amount of the dung the value of GCV decrease. The reason behind this is, as we increase the dung content the moisture and ash content values also increase and it is well known that high moisture value in the fuel will have low energy content. This is the reason that set A has maximum GCV values because it has low ash and moisture content values. On the other hand combinations of set D have minimum GCV values because it has high ash and moisture content values. This occurs because set A has minimum (20%) dung percentage value while set D has maximum (80%) dung percentage values.

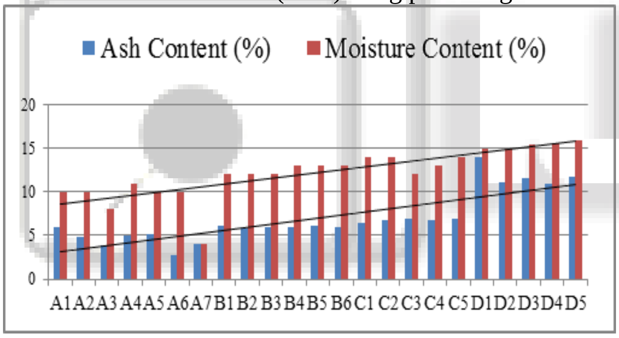

Fig. 2: Ash and moisture content of all combinations of all sets

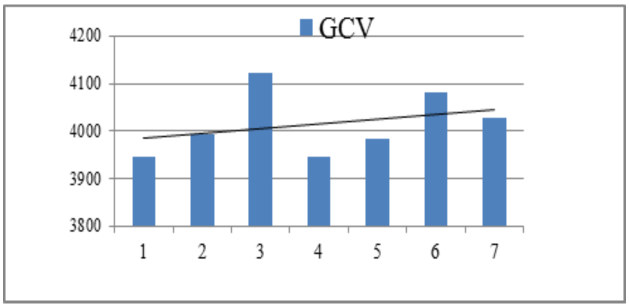

Fig. 3: GCV of combinations of set A

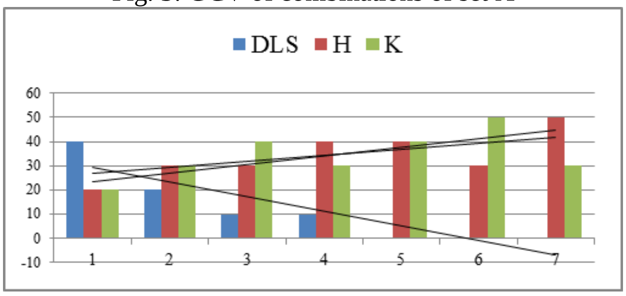

Fig. 4: Percentage of kirri, husk and DLS of set A

5) Above given graphs shows the relation among the values of GCV and values of percentage amount of Kirri, husk and dried leaves and sticks for the set A. These graphs clearly shows that there is a positive correlation among percentage value of Kirri, husk and GCV values means as the values of Kirri and husk increases the value of GCV also increase. While there is a negative correlation appears between percentage value of dried leaves and sticks and GCV values means as we decrease the percentage values of dried leaves and sticks the GCV values increases.

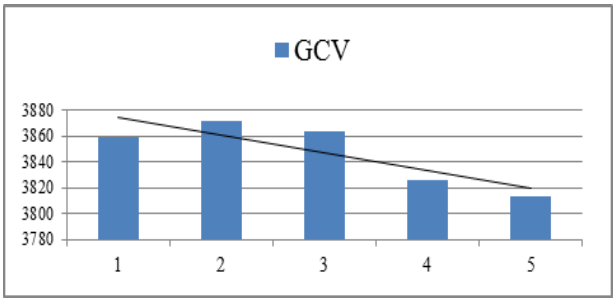

Fig. 5: GCV of combinations of set B

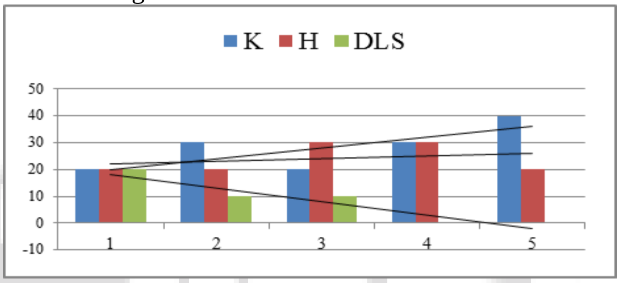

Fig. 6: Percentage of kirri, husk and DLS of set B

6) Above given graphs shows the relation among the values of GCV and values of percentage amount of Kirri, husk and dried leaves and sticks for the set B. These graphs clearly show that there is a negative correlation among percentage value of Kirri, husk and GCV values. While there is a positive correlation appears between percentage value of dried leaves and sticks and GCV values.

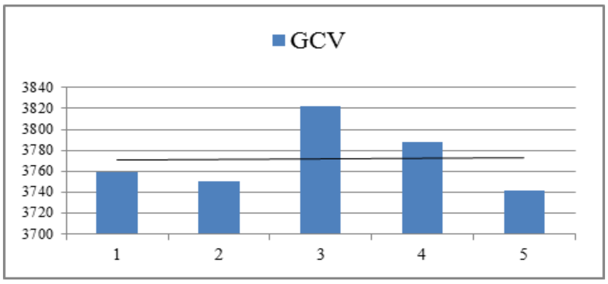

Fig. 7: GCV of combinations of set C

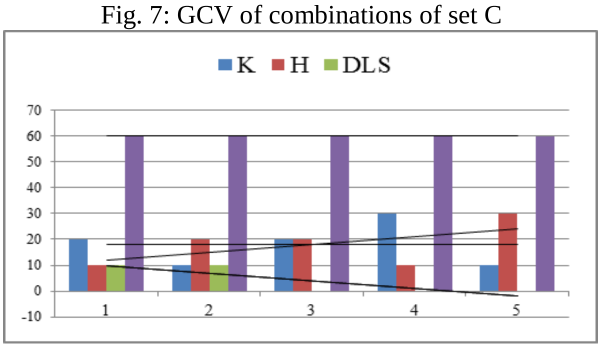

Fig. 8: Percentage of kirri, husk and DLS of set C

7) Above given graphs shows the relation among the values of GCV and values of percentage amount of Kirri, husk and dried leaves and sticks for the set C. These graphs clearly show that there is a positive correlation among percentage value of Kirri, husk and GCV values. While there is a negative correlation appears between percentage value of dried leaves and sticks and GCV values.

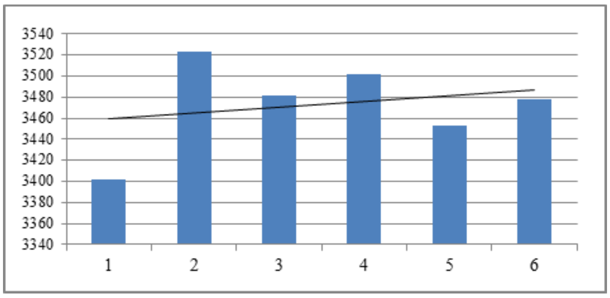

Fig. 9: GCV of combinations of set D

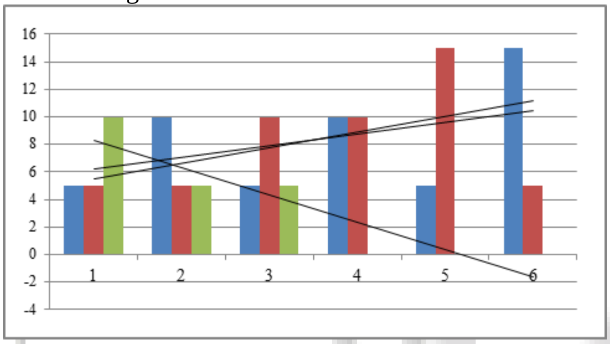

Fig. 10: Percentage of kirri, husk and DLS of set D

8) Above given graphs shows the relation among the values of GCV and values of percentage amount of Kirri, husk and dried leaves and sticks for the set D. These graphs clearly show that there is a positive correlation among percentage value of Kirri, husk and GCV values. While there is a negative correlation appears between percentage value of dried leaves and sticks and GCV values.

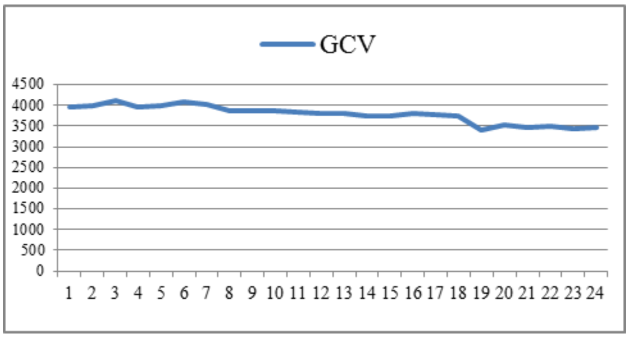

Fig. 11: GCV of all combinations of all sets

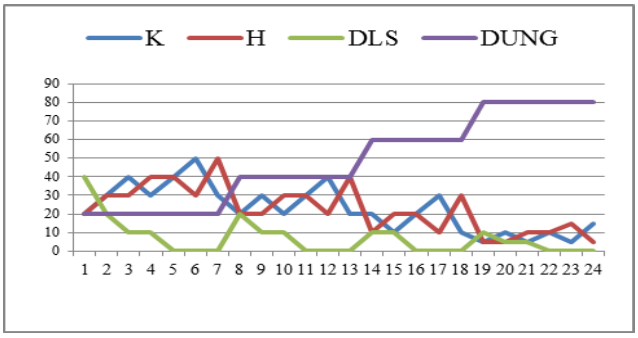

Fig. 12: Percentage amount of dung, kirri, husk and DLS

9) Above given graphs shows the relation among the values of GCV and values of percentage amount of Kirri, husk, dried leaves, sticks and dung for the all combinations of all sets. These graphs clearly show that there is a positive correlation among percentage value of Kirri, husk, dried leaves, sticks and GCV values. While there is a negative correlation appears between percentage values of dung and GCV.

10) The correlation coefficient for GCV and percentage amount of kirri is 0.8311, which indicates a good positive correlation between them. The correlation coefficient for GCV and husk is 0.7621 which again indicates a good positive correlation between them. The correlation coefficient between GCV and Dried leaves, sticks is 0.2478 which indicates a low level of positive correlation between them. The correlation coefficient between GCV and dung is -0.9532 which indicates a highly negative correlation between them.

IV. CONCLUSION

According to the above observations it can be concluded that kirri obtained from lac industry can be efficiently utilized for the energy production as its energy production potential is equal to the coal. This kirri can be used in the lac industry itself so that the energy required from the energy grid can be reduced. Presence of dung decrease the energy production potential of the kirri, so if one want to use dung it must be of very low moisture or dry and with very low ash content. Excess amount of dried leaves and sticks also decrease the energy potential of the kirri. Among above given different combinations highest energy production potential was from the combination in which the percentage amount of dung, kirri, husk and dried leaves with stick was 20,40,30,10 respectively which has produced 4124 kcal per kg with ash content of 3.8% and 8% moisture content. So the biodegradable waste from different industries can be recycled in energy production through briquetting.

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