ISSN: 0974-5823 Vol. 7 No. 4 April, 2022

International Journal of Mechanical Engineering

Energy recovery from Tea Waste blended with Rice Husk as an alternative fuel source

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Abstract

The exponentially increasing demand of energy require alternative and cleaner source for energy generation to meet the demand. The study proposes biomass briquette prepared from rice husk and tea waste using corn starch as binding agent. The biomass briquette is a low cost method of energy generation from waste material that could provide the cleaner energy and effective utilization of waste material. The briquette of different composition was prepared and proximate analysis of briquette were carried out in laboratory using standard methods of IS 1350 and ultimate analysis of biomass was carried out using ASTM methods. The results suggest that mixing of tea waste with rice husk improves the properties of briquette and increased the potential of energy generation. The mixing of tea waste enhances the calorific value and carbon content of the briquette with low ash content.

Keywords: Briquette, rice husk, tea waste, alternate energy

1. Introduction

The urbanization has grown more than 50% throughout world by 21st century and population living in the urban areas consuming more than 50% of overall energy and 60% of CO_2 emission (Behera and Dash, 2017). The population shifting towards urban centers also increasing load on the energy generation with higher demand every year, consumption of fossil fuels and emission of greenhouse gases (GHGs) (Shahbaz et al., 2015). Renewable energy have been explored in last 2 decades potentially to generate the energy and reduce the GHG emission to meet the SDG 2030 goals (Elavarasan et al., 2020). The renewable energy generation from solar, wind and biomass have been identified as ecological options for renewable development in India. Biomass is formed by the naturally available plant, agriculture and forest residue which could be used for energy generation. The availability of dry biomass have wide applicability as alternative source of energy generation with lower GHG emission also recommended by UNFCCC, Spain 2019, to review the methodological approaches for calculating emission reductions achieved by project activities that result in reduced use of biomass in households (Elavarasan et al., 2020; Mazorra et al., 2020). The utilization of agricultural waste material such rice husk have shown greater economic viability as alternative fuel (Silva et al., 2021). However, the lower bulk density of rice husk increases difficulty in handling and hence compressed to develop briquette.

Briquettes and pellets are the transformed form of biomass compacted to reduce the space required in storage and transportation, with increased density up to 1000-1200 kg/m^3 of loose biomass, and the volume reduced by 8–10 times (Cui et al., 2019; Thekedar et al., 2021). The density of agriculture residue or industrial waste are reduced and conglomerated with different waste type to form the briquette through direct and indirect transformation. The former approach is based on combustion and latter approach uses pyrolysis for the transformation of biomass. Rice husk provides an energy efficient material for energy generation with a calorific value in the range of 3,394 to 3,681 Kcal/kg equivalent amount of heat generated from per kilogram of material (Deshannavar et al., 2018). The higher combustion efficiency (80.39%) and availability in larger quantity prioritize the rice husk based briquettes over other agricultural waste material such as sugar cane bagasse, wheat straw, hay, starch, corn stalks etc (Awulu et al., 2018; Deshannavar et al., 2018). The good quality briquette also require binders, appropriate particle size to resist the humidity and temperature of external environment. The rice husk briquettes are also blended with different materials such as coconut, corn, tea to produce the more composite material with high calorific value.

The handling of rice husk is a cumbersome process and require large space for storage. India alone produces 31 million tons of rice husk annually generated from the milling operation of paddy crops @ 0.28 kg per kg of milled rice (Brand et al., 2017; Saeed et al., 2021). Large part of rice husk is being utilized in industrial boilers as alternative energy source for dyeing, paper mills, rice mills, biomass-based power plant for steam generation. The various researchers illustrated the successful application of biomass blended with different materials having low moisture content and high calorific value for energy generation (Ahiduzzaman and Islam, 2016; Brand et al., 2017). Amaya et al., (2007) designed rice husk briquette mixed with activated carbon to improve the mechanical properties of briquette. Yahaya and Ibrahim (2012) developed two different composition of rice husk briquette. In the first sample starch was used as binding agent, whereas another sample was prepared using gum Arabic as binders. Author performed the water boiling test and flame test on briquettes prepared manually. Ndindeng et al. (2015) developed briquette of different compositions with different binders to determine the compactness and calorific value. All form of briquettes were found outperforming charcoal. Suryaningsih and Nurhilal (2018) performed study to identify the rate of decomposition of lingo-cellulosic compounds in rice husk-based briquettes compared to charcoal. The tapioca starch was used as binder in briquette and results illustrate the high calorific value and compressive strength of over fossil fuel used in domestic activities. Deepak et al. (2019) prepared the briquette from Areca leaves with starch as binder at high pressure. Saeed et al. (2021) performed the analysis of variation in moisture content of briquette blended with lignin content. The durability of the briquettes were determined using physio-chemical analysis and it was observed that briquette with 14% of moisture content provides highest calorific value. Ajith Kumar et al. (2022) developed briquette with different composition including rice husk, sawdust, dry leaves and strength of briquettes were determined using proximity analysis and observed that briquette developed from dry leaves produces highest calorific value and appropriate material is required to be identified for blending as blending with inappropriate material may also reduce calorific value of briquette.

It was observed that most of the studies uses rice husk with coconut, saw dust and corn shell and worked on the variation in the physical composition of briquette. This study focuses on the development of briquette using rice husk and tea waste. The composition of rice husk and tea waste varied in different proportion to obtain the appropriate combination with binders. The objective of this study to produce bio-briquettes from waste tea and rice husk by varying their proportion and using appropriate additives /binders, and develop the suitable prototype model for energy recovery from tea waste and rice husk.

2. Material and Methods

2.1. Biomass material

The biomass used for the study area rice husk and tea waste. Rice husk was collected from rice mills of Maharashtra and tea waste was collected from various hotels of Maharashtra. The collected biomass was air dried for 7 days to reduce the moisture content. The biomass was shredded to pass through the sieve of 50 micron. The powder form of biomass used for the briquette formation is shown in Figure 1.

2.2. Briquette formation

The various combination of biomass materials were prepared and tested to obtain the briquette with highest calorific value and maximum heat generation. The composition of rice husk and tea waste was varied to obtain the different samples, as shown in Table 1. The biomass mixture was blended with corn starch by 15%

of the weight of the mixture to prepare the briquette. To enhance the binding capacity of starch water was added in appropriate ration and biomass was mixed thoroughly. The steam was passed through the prepared mixture for 30 seconds to make the biomass soft and spongy (Soltani et al., 2015).

Rice Husk

Tea Waste

Figure 1: The shredded rice husk and tea waste samples

The prepared mixture was compressed using cylindrical piston press. A mold of 50 mm diameter and 150 cm in height was used for briquette formation. The mold was used with oil on inner surface to ensure the surface tension in biomass compression. The compacted briquette was air dried for 24 to 48hours after taking out from mold. The briquette of various samples are as shown in Figure 2.

Sample A

Sample B

Sample C

Sample D

Sample E

Figure 2: Briquette with varied composition

Table 1: Composition of different briquette samples

S.No.	Sample Name	Raw Material	Briquette composition
1	Sample A	Rice husk and Tea waste	50%, 50%
2	Sample B	Rice husk and Tea waste	40%, 60%
3	Sample C	Rice husk and Tea waste	30%, 70%
4	Sample D	Rice husk and Tea waste	60%, 40%
5	Sample E	Rice husk and Tea waste	70%, 30%

2.3. Proximate analysis of Briquette

2.3.1. Moisture Content

The moisture content of the briquette was determined by using oven drying standard method of proximate analysis as defined in IS 1350 (Part I): 1984. A sample of 1 g placed in oven after taking the weight of empty container. The sample is heated at 200°C until constant weight is obtained. The sample is weighted after cooling down to room temperature in dessicator. The moisture content is determine using following formula:

$$Moisture\ Content, MC\ \ (\%) = \frac{M_2 - M_3}{M_2 - M_1}$$

Where, M is the moisture content of sample in percentage, M_2 is the mass of sample in vessel before heating, M_3 is the mass of sample in vessel after heating and M_1 is the mass of vessel.

2.3.2. Ash

The ash content of the briquette was determined by using standard method of proximate analysis as defined in IS 1350 (Part I): 1984. An air dried sample of 1 g placed in muffle furnace at temperature 500°C for 30 mins and temperature raised to 815°C for another 30 mins. The sample removed from furnace after 1 hour allowed to cool down in dessicator. The ash content is determine using following formula:

$$Ash\ (\%) = \frac{M_3 - M_4}{M_2 - M_1}$$

Where, M_1 is the mass of vessel, M_2 is the mass of vessel and sample, M_3 is the mass of vessel and ash, M_4 is the mass of vessel after brushing the ash.

2.3.3. Volatile Matter

The volatile matter content of the briquette was determined by using standard method of proximate analysis as defined in IS 1350 (Part I): 1984. An air-dried sample of 1 g passed through 212 micron sieve, placed in muffle furnace at temperature 900°C for 7 mins. The sample removed from furnace and allowed to cool on metal plate for first 5 mins and then in dessicator. The volatile matter content is determine using following formula:

$$Volatile\ Matter, VM\ (\%) = \left(\frac{M_2 - M_3}{M_2 - M_1}\right)100 - M_0$$

Where, M_o is the percentage of moisture in sir dried sample, M_1 is the mass of empty crucible with lid, M_2 is the mass of crucible with lid and sample before heating and M_3 is the mass of crucible with lid and sample after heating.

2.3.4. Fixed Carbon

The fixed carbon content of the briquette was determined by using standard method of proximate analysis as defined in IS 1350 (Part I): 1984. The percentage of fixed carbon is determined by mass balance technique using following formula:

$$Fixed\ Carbon, FC\ (\%) = 100 - (MC + VM + Ash)$$

2.3.5. Gross Calorific Value

The gross calorific value of the briquette was determined by using bomb calorimeter method of proximate analysis as defined in IS 1350 (Part II): 2017. The instrument generates the current to ignite the sample for determining calorific value and placed inside the water jacket.

2.4. Ultimate analysis of briquette

The ultimate analysis of briquette was performed to determine the elemental composition of briquette samples. The carbon and hydrogen were determined to identify the reactivity and oxygen required for the combustion of sample. The carbon, sulphur and nitrogen were determined for accounting the compounds generated during emission. The standard method of ASTM D-5373 were employed to test the carbon, hydrogen and nitrogen content in sample and ASTM D-3176 was used for oxygen and ASTM D-4239 was used for determination of sulphur. The carbon, nitrogen and hydrogen are determined using following equations:

$$Carbon, C = C_a * \frac{100}{100 - M_a}$$

$$NItrogen, N = N_a * \frac{100}{100 - M_a}$$

$$Hydrogen, H = (H_a - 0.1119 * M_a) * \frac{100}{100 - M_a}$$

Where, C_a is the carbon measured in furnace at 900°C, N_a is the nitrogen measured in furnace at 900°C, H_a is the hydrogen measured in furnace at 900°C and M_a is the moisture content of the sample.

3. Results and Discussion

3.1. Ultimate analysis of rice husk and tea waste

The ultimate analysis of biomass consisting rice husk and tea waste was determined to identify the elemental composition of material using standard ASTM test methods. All the parameters were found high in tea waste, signifies the better composition and high value of tea waste for the briquette formation, as shown in Table 2. However, rice husk generated in large concentration and briquette formation allows the effective utilization of rice husk waste and blending with the tea waste enhances the properties of briquette to generated large heat energy. The carbon content of the material is the most vital property which increases the time of combustion process and hydrogen assist in the complete combustion of material and greater oxygen content in the material allows the continuous burning of material. The comparative of elemental composition of rice husk and tea waste is shown in Figure 3.

Table 2: Ultimate analysis of rice husk and tea waste

S. No	Test Parameter	Test Method	Rice Husk (%)	Tea Waste (%)
1	Carbon (as C)	ASTM D-5373	39.15	46.95
2	Hydrogen (as H)	ASTM D-5373	5.09	6.35
3	Nitrogen (as N)	ASTM D-5373	0.44	2.68
4	Sulphur (as S)	ASTM D-4239	0.12	0.20
5	Oxygen (as O)	ASTM D-3176	28.94	33.30

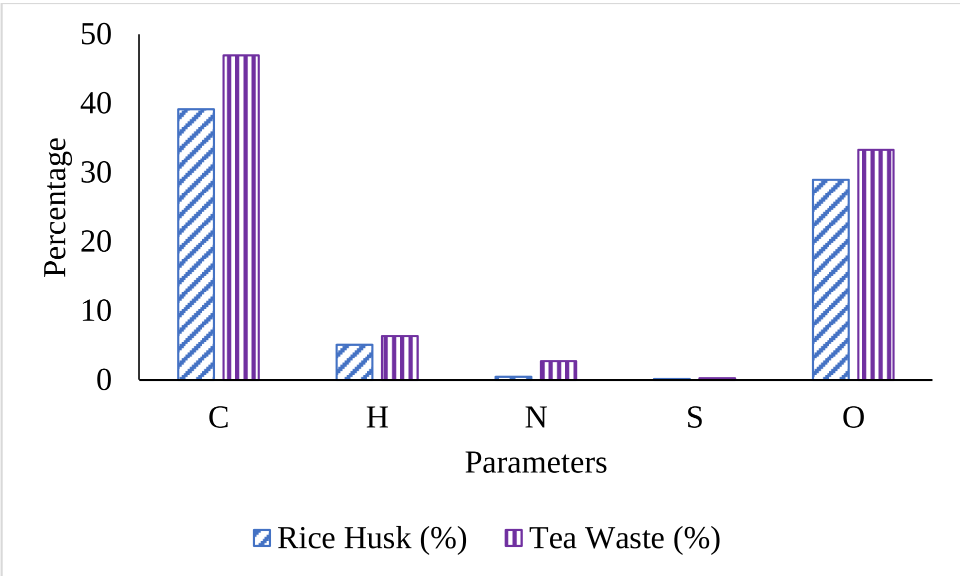


Figure 3: Ultimate analysis of elemental compounds

3.2. Moisture content of briquette

The moisture content (MC) is the significant factor for the determination of potential of material used as alternative to fuel sources. The less concentration of moisture in material represent the better quality. However, certain amount of moisture content is required to prepare a compact mixture and fix all the ingredients in defined shape with minimum pore spaces. The MC in tea waste and rice husk was found as 6.92% and 7.68%, comparative to each other, as shown in Figure 4 and mixture of biomass also doesn't show greater fluctuation in MC of mixture. The MC of mixture increases marginally as the concentration of rice husk increased in sample D and E, as shown in Figure 5. The literature also suggests that MC below 10% is optimum for the briquettes. All the samples were found with MC less than 10% and minimum MC was observed in sample A as 6.99%.

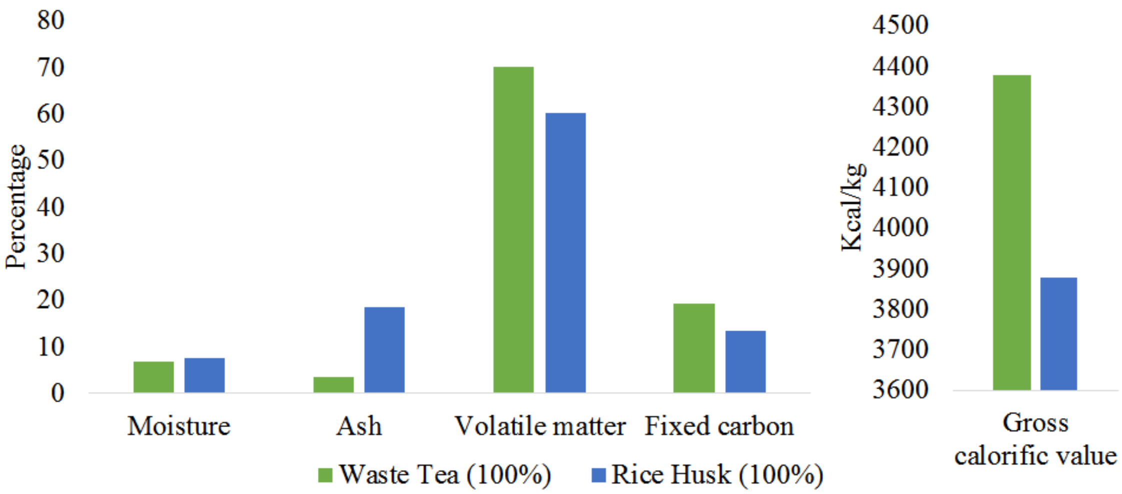
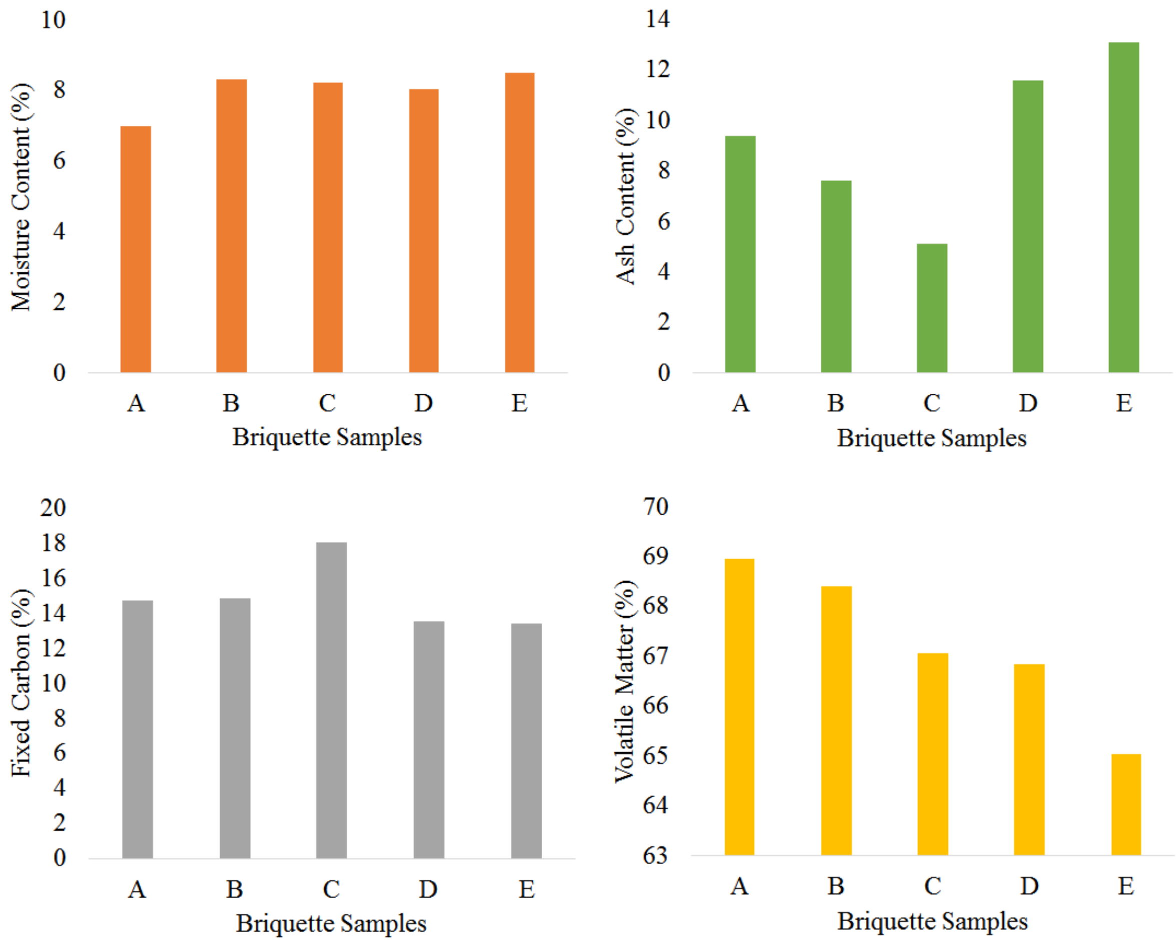


Figure 4: Proximate analysis of rice husk and tea waste before mixing



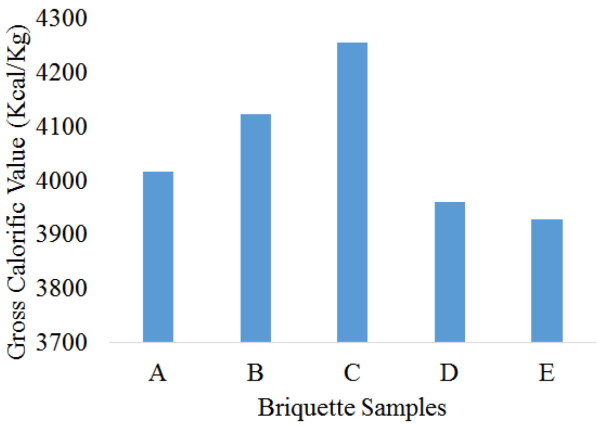


Figure 5: Proximate analysis of rice husk and tea waste mixture in different proportions

3.3. Ash content of briquette

The greater concentration of ash is detrimental to the combustion process and directly represents the waste material. The ash content increases the waste generation and energy consumption in the burning of non-flammable compounds. The literature suggest that ash content above 10% is undesirable and start hindering the combustion process. Sample D and E were found with high ash content compared to desired value, whereas the minimum ash content was found in sample C, as shown in Figure 5, where the minimum concentration of rice husk was used in the preparation of briquette.

3.4. Volatile Matter of briquette

The volatile matter consists of various compounds which are combustible in nature and allows the better ignition of material. The faster burning of material provides quick energy but also emit large amount of gases. The tea waste generated the volatile matter as 70.21% and rice husk produces 60.23% of volatile matter, whereas the mixture of biomass produces volatile matter in the range of 65-69%. All the samples are acceptable depending upon the application of briquette. The blending of rice husk with tea waste in equal proportion produces the maximum volatile matter in sample A, as shown in Table 3.

3.5. Fixed carbon of briquette

The fixed carbon represents the amount of carbon present in briquette and directly proportional to the calorific value and inversely proportional to the ash content. The results illustrate that increase in ash content causes reduction in fixed carbon and vice versa. The presence of fixed carbon in high percentage allows the longer burning of the briquette and provides better energy. Sample C of briquette gives maximum fixed carbon and minimum ash content, as shown in Figure 5. In the same sample maximum concentration of tea waste was mixed with the rice husk.

3.6. Gross calorific value of briquette

The calorific value of biomass and mixer illustrate the clear difference between the two. The tea waste produces high calorific value of 4377 Kcal/kg compared to calorific value of rice husk as 3879 Kcal/kg. Among the five samples prepared, maximum calorific value was found in Sample C as 4256 Kcal/kg, where maximum proportion of tea waste was used to prepare the briquette. The sample C also provides high fixed carbon and low ash and volatile matter, as shown in Table 3. Results illustrate that briquette with highest calorific value have lowest ash content and maximum fixed carbon. The calorific value of briquette could be further increased with the blending of tea waste in high proportion, however considering the large quantity of rice husk generated compared to tea waste, 30:70 ratio was adopted to perform the analysis.

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Table 3: Proximate analysis of rice husk and tea waste mixture in different proportions

S. No	Test Parameter	Test Method	Test Result of Bio-Briquette Rice Husk (%): Waste Tea (%)				
			50:50	40:60	30:70	60:40	70:30
1	Moisture (%)	IS 1350 (Part 1)1984	6.99	8.31	8.24	8.05	8.5
2	Ash (%)	IS 1350 (Part 1) 1984	9.36	7.63	5.10	11.58	13.07
3	Volatile matter (%)	IS 1350 (Part 1) 1984	68.95	68.40	67.07	66.85	65.04
4	Fixed carbon (%)	IS 1350 (Part 1) 1984	14.70	14.85	18.02	13.52	13.39
5	Gross calorific value (Kcal/Kg)	IS 1350 (Part 2) 2017	4018	4123	4256	3961	3928

4. Conclusion

The population has increased many folds in last few years and subsequently the energy demand has also grown exponentially. At the same time, to meet the sustainable development goals (SDGs) target of 2030, there is stringent need to reduce the consumption of fossil fuels. The waste generated from industrial and agricultural sector provides ample quantity of material that can used for energy generation after required treatment. Rice husk and tea waste are mixed to form a briquette in this study and briquette were designed of different composition using corn starch as binder. The ultimate analysis shows that tea waste has high carbon, hydrogen and oxygen content that allows the greater combustion time compared to rice husk. The proximate analysis shows higher fixed carbon, calorific value of sample C consist high proportion of tea waste compared to rice husk (30:70). The sample C also produces low ash content and volatile matter. The study suggest that tea waste has a good potential to be used in briquette formation and could produce high energy compared to rice husk. The better composition of tea waste and rice husk briquette could solve the problems associate with utilization of waste material and alternate energy requirement.

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