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Preparation and Characterization of Biomass Briquettes Using Corncob, Rice Husk, Sawdust and Coco Peat

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Abstract

The experiment conducted during July, 2023, at the college of agricultural engineering, IGKV Raipur Chhattisgarh, India focused on converting corncob, rice husk, sawdust, and coco peat into biomass briquettes as an alternative energy source to fossil fuels. Various compositions of biomass briquettes were prepared and characterized based on their physical and thermal properties, as well as their burning capacity using the Water Boiling Test (WBT). Among the nine compositions tested, sample L_4 (a 50:50 ratio of corncob and sawdust) showed the best results, with a bulk density of 610 kg m^{-3}, moisture content of 2.75%, and solid content of 98.1%. Proximate and ultimate analyses were conducted to determine the composition and properties of the briquettes. Sample L_4 exhibited the highest fixed carbon content at 47.95%, and the lowest ash content at 3.69%, which is beneficial for combustion efficiency. In contrast, the corncob and coco peat combination in sample L_9 (40:60 ratio) had the highest volatile matter at 62.33%, promoting easy ignition. The ultimate analysis of sample L_4 revealed an elemental composition of 57% oxygen, 36% carbon, 6% hydrogen, and around 1% nitrogen, with a thermal efficiency of 28%. During the WBT, sample L_4 evaporated an average of 210.42 ml of water, and its calorific value was the highest among all samples at 18 MJ kg^{-1}. The study concluded that sample L_4, due to its favorable properties, is a promising candidate for alternative energy applications.

Keywords: Biomass briquettes, corncob, sawdust, proximate analysis, ultimate analysis

1. Introduction

The World Health Organization (WHO) has indeed highlighted the prevalence of traditional cooking practices and their impact on global health. Cooking with open fires or inefficient stoves can result in high levels of indoor air pollution, which leads to several respiratory diseases and other health issues (Anonymous, 2022). It is estimated that around three billion people (40% of the global population), are reliant on such cooking methods (Lombardi et al., 2017 and Panwar, 2010). More than one-third of the world's populations (2.8 billion people) rely on various forms of solid fuels (firewood, charcoal, dung, residues, etc.) and kerosene in meeting their energy needs (Stoner et al., 2021). Household air pollution from burning biomass fuels such as wood, charcoal, and animal dung contributes to an estimated 4 million premature deaths annually, disproportionately affecting developing countries where reliance on these fuels is high. (Bickton et al., 2020). It is important to remember that pollutant emissions into homes lower indoor air quality, resulting in a variety of diseases linked to solid-fuel inhalation, including high blood pressure, acute respiratory infections, cataracts, blindness, low birth weight, infant mortality, and, in particular, chronic obstructive pulmonary disease (Panwar and Rathore, 2015, Rubio et al., 2010). Indoor air pollution from the combustion of solid fuels, such as wood, coal, or biomass, is a significant health concern in many parts of the world. These risks are especially pronounced for women and children, as they often spend more time indoors in proximity to the source of pollution (Bielecki et al., 2014). Cardiovascular disorders, including high blood pressure (hypertension), can affect both men and women. However, certain factors can make women more susceptible to developing high blood pressure (Thangavel et al., 2022 and Islam et al., 2023). Briquettes was made by the biomass composition after sun drying, briquettes are burnt to produce heat which is used to convert water to steam, which drives turbines to generate electricity. Briquettes can be used in residential, commercial, and industrial applications, making it a versatile energy. In rural areas, the burning of wood is a common practice for cooking the food, but as the briquettes are used for heat generation as an alternative source, they can be used for cooking the food. Harvesting, processing, and transporting biomass materials is a labor-intensive workforce, which provides employment opportunities for local communities' fuels (Javed et al., 2016). Direct combustion of biomass results in release of harmful pollutants such as particulate matter, carbon monoxide, and volatile organic compounds, leading to indoor air pollution. Carbonized briquettes produce less smoke and emissions when compared to un-carbonized briquettes. When burnt, results in improved indoor air quality and reduced health risks for individuals which make them better for cooking and heating (Chen et al., 2009). The ash content of agricultural residues plays a significant role in the briquetting process. Agricultural residues with an ash content of less than 4% are preferred for briquetting because they have a reduced slagging potential. Slagging refers to the formation of molten or partially fused ash deposits during combustion, which can negatively affect the efficiency and performance of the briquettes (Lam et al., 2008). These traditional cooking methods release large quantities of harmful pollutants, including fine particulate matter (PM2.5) and carbon monoxide (CO), among other toxic substances (Barbour et al., 2021). Nitrogen dioxide (NO_2) is a harmful gas that can have adverse effects on human health, particularly on the respiratory system. The WHO has set a limit for indoor hourly exposure limit for NO_2, the geometric mean highest hourly average NO_2 concentration was 723 ppb (geometric standard deviation (GSD) 2.6) and geometric mean 24-hour average concentration was 96 ppb (GSD 2.6), 4.4 and 2.9 times greater than WHO indoor hourly (163ppb) and annual (33 ppb) guidelines, respectively (Kephart et al., 2020). Thus the aim of the study was to convert corn cob, rice husk, sawdust, and coco peat into biomass briquettes.

2. Materials and Methods

The experiment was conducted *kharif* (July 2023), research study area with longitude 81^{0}65'' and latitude 21^{0}23'' at the college of agricultural engineering, IGKV Raipur Chhattisgarh, India.

2.1. Biomass collection

Basic material of this study includes maize cobs, rice husk, cocopeat, sawdust and corn starch which was used as a binder to enhance the adhesion and strengthening briquettes. Maize cobs were collected from mungeli farm fields, rice husk from a rice mill, sawdust was collected from a sawmill and cocopeat was collected from a nearby market. The reason why the residues and binders were selected is that they are frequently thrown or flared, posing risks to both human and ecological health. They are also produced in vast quantities, and are simple to obtain, inexpensive, and are easily available.

2.2. Raw materials

The raw materials used in the preparation of briquettes include corncob, rice husk, saw dust and coco peat.

2.2.1. Grinding and sieving of maize cobs

A byproduct of the maize crop, maize cobs are a lignocellulosic plant material that is rich in energy and organic elements. For every tonne of maize that is shelled, about 180 kg of cobs are produced. However, lignin (5.6%), water soluble carbohydrate (1.1%), and protein (2.5%) are observed to be present in maize cobs (Kaliyan and Morey, 2010).

2.2. Sawdust

The different types of wood can produce sawdust particles of varying sizes. Generally, sawdust particles range in size from 0.3 to 0.6 mm. However, it is important to note that this is a general range and can vary depending on factors such as the type of wood, the cutting or grinding method used, and the equipment involved in the wood processing.

2.2.3. Cocopeat

Natural fibre called cocopeat is derived from the husk of coconuts. Cocopeat is the byproduct of coconut husk extraction. For the production of various products like cocopeat tablets, blocks, briquettes etc. cocopeat should be sun-dried. Cocopeat contains about 71.80% volatile matter, 14–20% moisture, 22.05% fixed carbon, 6.14% ash, and 1.14% silica.

2.2.4. Rice husk

The composition of rice husk can vary, but on average, it contains approximately 60–65% volatile matter, 10–15% fixed carbon, and 17–23% ash. Volatile matter refers to the substances that can easily vaporize, while fixed carbon refers to the solid carbonaceous material remaining after volatile matter has been driven off. Ash represents the inorganic mineral content in the husk.

2.2.5. Process of making of biomass briquettes

It was seen from the Figure 1, the flowchart explains the process of production of biomass briquette starting from biomass collection, then the drying process will be done , mostly sun drying is preferred to dry the matter, then it is grinded to make fine and smooth to make binding perfect and mix well. The mixture of briquette is compact to give shape for better drying and storage.

2.2.6. Preparation of composition for biomass briquettes production

Briquetting is the process of exerting pressure on a mass of particles, with a binder, to create a compact product with superior burning properties, a high bulk density, and low moisture content. By combining them with corn starch, the combination of corn cob, rice husk, and coco peat are the main ingredients employed in the creation of briquettes. The treated mixture was fed into the briquette-making machine to prepare the briquettes. The briquettes, which were obtained from biomass, should be dried for 3 to 4 days in the sun at 32°C. A briquette in their dried form is an ideal substitute for

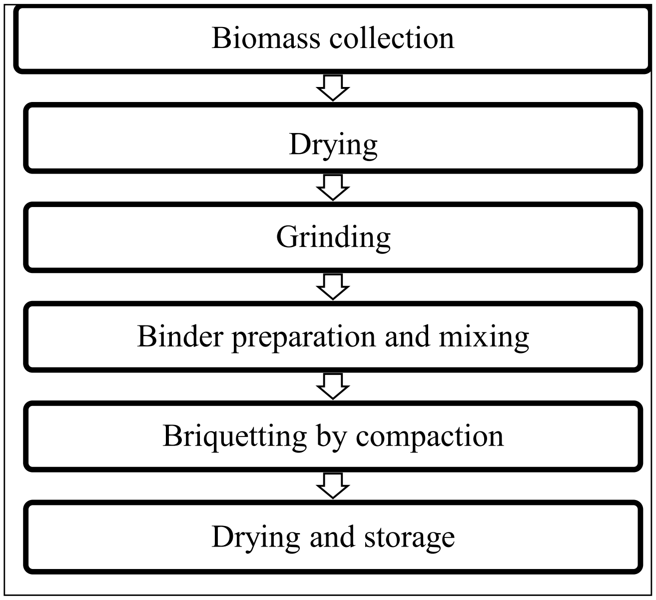

Figure 1: Flowchart for the production of biomass briquettes

firewood. Biomass materials with a moisture content of 10-15% are suitable for briquetting, but higher moisture content materials must be dried out. The material is screened, cut, and grounded before being pneumatically transferred into storage bins to unify the moisture content and separate heavier and matchlock particles. To create ground particles, raw material is put into the hammer mill of the briquetting machine. The corncob is grinded by using the cylindrical grinding type at a speed of 50,000 to 1,20,00,0 feet minute^{-1} to make the cob fine in size. Compression increases the material's temperature, softening it and forming intrinsic binders that unite the substance.

Table 1 shows that the different mixture ratios for preparing and making the briquettes. Total nine treatments from L_1 to L_9 are taken with composition of corncob rice husk, sawdust, coco peat with different ratio of propositions.

2.2.7. Proximate and ultimate analysis of the briquettes

Proximate and Ultimate analysis of the fuel was carried out in order to investigate the feed stock characteristics of the produced briquettes. The sample was heated in an oven at temperature of 105.5°C for 24 h or until constant mass is obtained, the moisture content (MC) was determined using ASTM D 3173–87 standard (Rambo et al., 2020). The volatile matter (VM) was also evaluated using 1 g of sample dried in muffle furnace at 600°C±50 for 6 min according to method ASTM D 3175–07 (Rambo et al., 2020). The ash content was determined using the ASTM D 3174–04 standard, which removes organic elements at high temperatures in a furnace at 700°C. Water boiling test (WBT) should performed by adding water to fill the pot's volume by 2/3. To reduce losses, the pot was maintained on the heat and its lid was pushed up. The pot's center portion had a thermometer placed there. For testing, 300 g of each type of briquettes were used. Ambient temperature and the starting temperature of the water in a pot were also measured. After putting out the fire, the setting time was noted. It was noted that the water's final temperature reached boiling and the average water boiling time was also noted (Table 2). As long as there were still logs available, keep the fire on until the water vaporizes. The pot lip was quickly removed, and vaporization continued for another 20 minutes. Separated from the cook burners, the pot was allowed to cool for two hours before the volume of water was measured (Rathore, 2008). To calculate briquettes calorific value a bomb calorimeter was used.

Table 1: Mixture ratios used for making briquettes

Composition	Treatment	Ratio
Corncob:Rice husk	L_1	50: 50
	L_2	60: 40
	L_3	40: 60
Corncob:Sawdust	L_4	50: 50
	L_5	60: 40
	L_6	40: 60
Corncob:Coco peat	L_7	50: 50
	L_8	60: 40
	L_9	40: 60

The value of fixed carbon (FC) was indirectly obtained by using the equation 1:

FC=100–(VM+MC+Ash) .... (1)

2.2.8. Water boiling test (WBT)

A modified water boiling test was carried out to assess the thermal performance of the produced biomass briquettes. The usual Water Boiling Test (WBT) was used to measure the thermal efficiency of the biomass briquettes. It is a basic tool that assesses how efficiently a stove uses fuel to heat water in a cooking pot and the amount of emissions created as a result. The ratio of heat energy entering the cooking pot to the energy content of the fuel consumed is known as the thermal efficiency of cook stove. The heat that enters the cooking pot has two quantifiable effects; firstly, it raises the temperature of the water from room temperature to boiling point and secondary, it evaporates the water. A known amount of water was heated in the stove using the standard WBT. The amount of fuel used to boil and evaporate the water was used to calculate the thermal efficiency used.

Thermal efficiency was calculated by following formula (Panwar, 2010).

Thermal efficiency=(sensible heat+latent heat)/(qauntity of fuel used ×calorific value)×100 ....(2)

$=W_{i\ Cp}(T_2-T_1)+L(W_i-W_f)$/(Qauntity of fuel used×Calorific value)×100 ....(3)

Where,

Wi=Initial weight of water,kg ,Cp=Specific heat of water J/kg °C

(4.187 kJ/kg °C); T_2=Final temperature of water, °C; T_1=Initial temperature of water, °C; W_f=Final weight of water taken, kg; L=Latent heat of water (540 kcal kg^{-1} or 2266 kJ kg^{-1})

3. Results and Discussion

3.1. WBT

It is observed from the Table 2, the briquette was entirely burned in the locally available cook burner and produced a consistent flame. Biomass briquettes combination L_4 had a higher burning rate and a greater amount of water evaporation and fuel utilized ratio than other combinations.

3.2. Analysis of physical characteristics of the prepared biomass briquettes

From the Figure 2, the Bulk density of substance is its mass $unit^{-1}$ volume. Bulk density of sample was calculated by core cutter method. Diameter of core cutter was 8 cm and height of core cutter was 12 cm. Volume of core cutter was 602.27 cm^3. Core cutter was filled with the sample. Weight of the sample was recorded by subtracting the total weight to core cutter. Then the density was determined for each sample as a ratio of weight to volume. This method was repeated for three times for each treatment to find out more accurate bulk density (Singh, 2013).

Table 2: Water boiling test

Treat-ments	Water boiling test				
	Fuel used (g)	Avg. time taken to burn (min)	Avg. water boiling time (min)	Avg. water evaporated (ml)	Avg. ratio of water evaporated to fuel used (ml g^{-1})
L_1	300	6.34	21.65	127.36	0.42
L_2	300	7.56	23.93	130.86	0.44
L_3	300	6.94	23.16	129.56	0.43
L_4	300	8.38	26.25	210.42	0.7
L_5	300	8.11	23.67	165.13	0.5
L_6	300	7.89	22.87	137.76	0.46
L_7	300	7.3	21.86	129.27	0.43
L_8	300	7.92	24.2	145.41	0.48
L_9	300	7.54	23.64	141.74	0.47

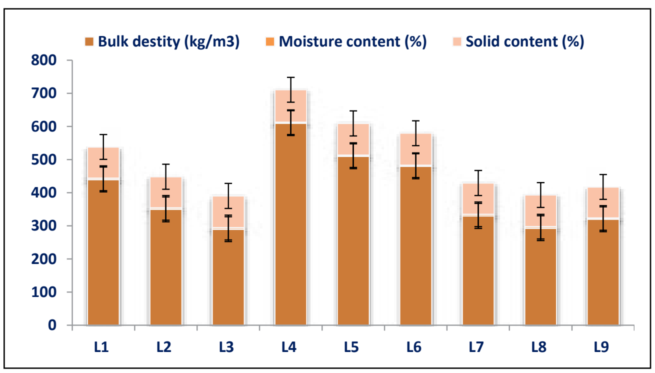

Figure 2: physical characteristics of the prepared biomass briquettes

Bulk dry briquette density was found to be low in sample L_3 at 290 kgm^{-3} and high in sample L_4 at 610 kgm^{-3}. Because of the shape and size (pore space size) of the particle used for making the briquette, the L_3 was having the composition of corncob: rice husk (40:60) and the presence of rice husk was 60% that make the sample lesser bulky or in case of sample L_4, the composition of corncob:sawdust (50:50) and the presence of saw dust is half in composition and fine in size. Thus, sample L_4 has higher Bulk Density than sample L_3. Moisture content was found to be low in sample L_4 at 2.75 % and high in sample L_7 at 5.03%. Lower moisture content of biomass briquettes led to high thermal efficiency and reduced amount of pollutant gases released. The amount of solid content was found to be low in sample L_2 at 94.14% and high in sample L_4 at 98.1%. The high solid content of biomass briquettes led to increased combustion efficiency as well as a longer burning time.

3.3. Analysis of calorific value of biomass briquettes

From figure 3, sample L_4 and sample L_9 was found to have the highest and lowest calorific value of 18 MJ kg^{-1} and 15.28 $MJkg^{-1}$, respectively. A bomb calorimeter was used to calculate the briquettes calorific value. A nichrome crucible containing one gram of log sample was used, and to assist the test, a long cotton thread was placed above the sample. A nichrome fuse

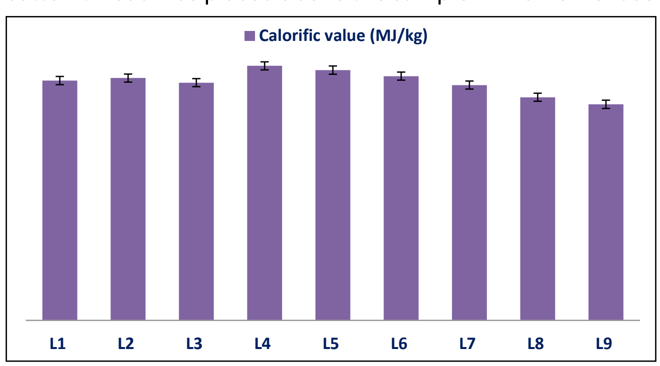

Figure 3: Calorific value of the prepared biomass briquettes

connected both of the calorimeter's electrodes, and oxygen gas was injected into the bomb at a pressure of about 25 to 30 atmospheric pressure. The temperature is automatically recorded while the water was continuously directed to homogeneity for two hours.

3.4. Ultimate analysis of different biomass briquettes

The ultimate analysis of a fuel refers to the determination of its elemental composition, including carbon, hydrogen, nitrogen, oxygen, and other elements. It provides important information about the fuel's combustion characteristics, such as the amount of air needed for complete combustion and the composition of the resulting combustion of gases are shown in figure 4.

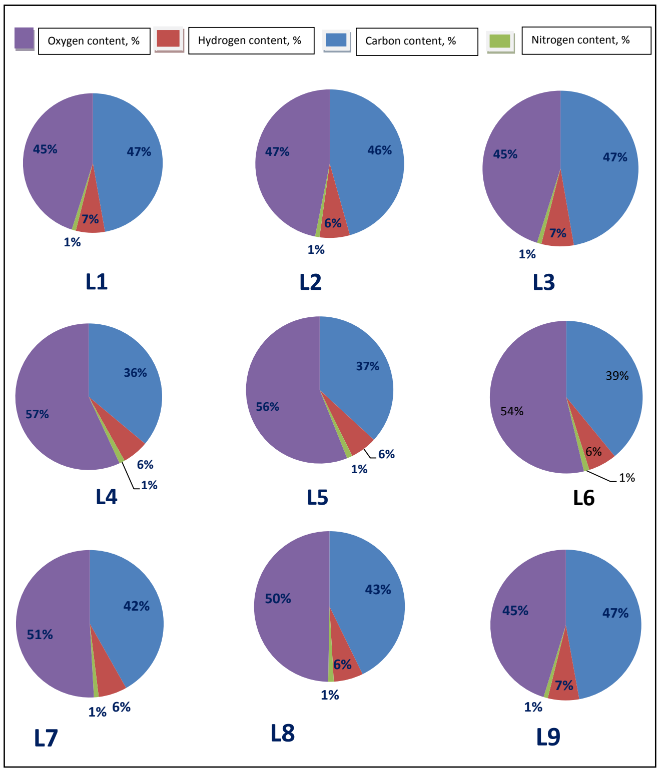

Figure 4: Ultimate analysis of the prepared biomass briquettes

Overall, based on the Water Boiling Test results, it can be concluded that the biomass briquettes combination L_4 was suitable for domestic applications. The high thermal efficiency and clean burning characteristics make it an efficient and convenient fuel source for heating purposes. The percentage composition of oxygen, hydrogen, carbon, nitrogen as well as thermal efficiency of the biomass briquettes sample L_4 was found to be 57%, 6%, 36%, approx 1% and 26% respectively.

3.5. *Proximate analysis of biomass briquettes*

The percentage by weight of fixed carbon, volatiles, ash and moisture content in the samples were determined by the quantity of fixed carbon and volatile combustible matter present in the fuel. The ash content is a significant parameter in determining the design of furnace grate, combustion volume, pollution control equipment and ash handling system.

From figure 5, it can be concluded that the biomass briquettes sample L_4 is suitable for domestic applications. The fixed carbon of the biomass briquettes sample L_4 was 47.95%, which was the highest when compared to the other samples. Heat generation is promoted by the presence of fixed carbon whereas high volatile matter content promotes easy ignition of fuel. When fixed carbon was high, gaseous pollutants such as CO, particulate matter, and other pollutants were less. The ash content of the biomass briquettes sample L_4 was 3.69%, which was less when compared to the other samples. High ash content can affect combustion efficiency, which causes fouling, and impact emissions. When the ash content is less, combustion efficiency is increased. Moisture content represents the amount of water present in the fuel. Moisture in biomass or other fuels has a negative impact on their combustion efficiency, because energy is required to evaporate the water before the combustion can occur. The moisture content of the biomass briquettes sample L_4 was the lowest i.e. 2.75%, resulting in the higher combustion efficiency. The volatile matter of the biomass briquettes sample L_4 was 45.6%. Volatiles are combustible materials that evaporate or vaporize when the fuel is heated. They contribute to the ignition and flame stability of the fuel. Fuels with higher volatile matter content tend to ignite more easily.

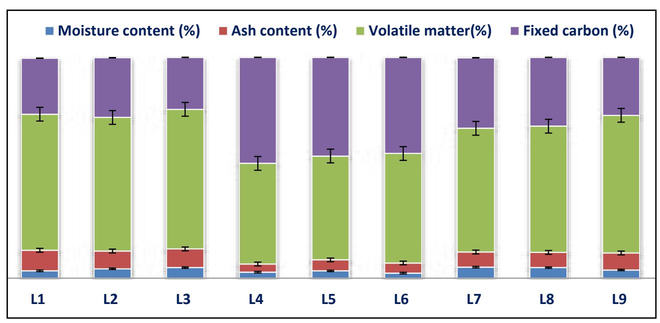

Figure 5: Proximate analysis of the prepared biomass briquettes

3.6. Thermal efficiency analysis of the prepared biomass briquettes

Figure 6 show that sample L_4 and L_9 had the highest and lowest thermal efficiency of 28% and 18% respectively. Sample L_4 had a higher bulk density, calorific value, higher burning rate, greater amount of water evaporated and low moisture content, therefore its thermal efficiency was high when compared to the other samples and similar to the sample L_9 had a low bulk density, low calorific value, lower burning rate, lower amount of water evaporated and high moisture content, therefore its thermal efficiency was low when compared to the other samples.

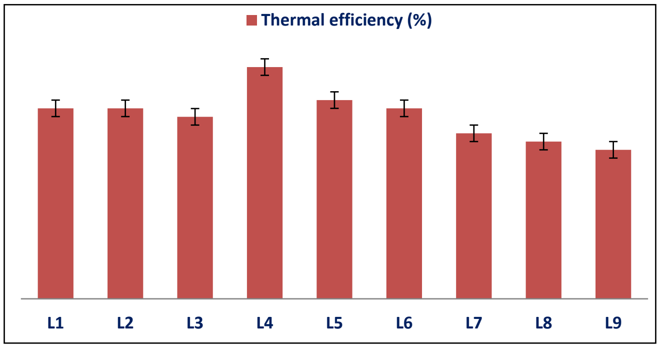

Figure 6: Thermal efficiency of the prepared biomass briquettes

4. Conclusion

Sample L_4 emerged as the most suitable biomass briquette for domestic applications, offering the highest thermal efficiency (28%) due to its high bulk density, calorific value, low moisture content, and efficient combustion characteristics. It also exhibited a favourable balance of fixed carbon and low ash content, leading to cleaner burning and reduced emissions. In contrast, sample L_9 had the lowest thermal efficiency (18%) due to its lower bulk density, calorific value, and higher moisture content.

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