PERIODICA
Journal of Modern Philosophy, Social Sciences and Humanities
ISSN NO:2720-4030 Volume 22 September, 2023

Using Of Binders in The Production of Briquettes

Kobilov Kh.X.
Bukhara Engineering Technological Institute, Bukhara, Uzbekistan.
E-mail: 2h.qobilov@mail.ru.
Sharipova N.R.
Bukhara Engineering Technological Institute, Bukhara, Uzbekistan.
E-mail: shnr_80@mail.ru.

A B S T R A C T

The adverse effect of the use of fossil fuels on the environment and public health has given rise to a sustained renewable energy research and development. An important component of global renewable energy mix is the use of loose biomass, including agricultural and forestry residues, to produce solid fuels in the form of briquettes. Briquettes play a significant role in bioenergy mix in developing and developed countries. The production of biomass briquettes often entails the collection, transportation, storage, processing, and compaction of loose biomass that meet specific quality parameters. The densification process often involves the addition of binders to improve the cohesive strength of the briquette material. This paper surveys recent literature from 2012 to 2021 to establish the current state of research on the use of binders in briquette production; and reviews current parameters used in assessing the quality of biomass briquettes with focus on mechanical and handling properties. While a number of quality parameters were identified, their assessment methodologies varied widely in the literature, thus necessitating standardization for comparability purposes. The review also includes factors affecting the wide production and adoption of biomass briquettes in most developing economies and proposes ways of overcoming the bottlenecks

A R T I C L E I N F O

Received: 20th July 2023
Revised: 20th August 2023
Accepted: 22th September 2023

K E Y W O R D S: densification; binders; briquettes; biomass; bioenergy; bio-economy

Introduction. Globally, biomass energy has continued to remain an important renewable energy component. It is an important part of national energy mix both for developed and developing countries towards achieving sustainable energy for heating applications, reducing environmental impact, creating bio-economies, reducing over dependence on fossil fuel, improving quality of rural and urban life, and for the production of various biofuels [1,2,3,4,5]. One of the challenges with the utilization of biomass is that they are mostly in loose form having low energy density. Biomass briquetting, a densification technology, is one of the technologies used in improving the potential energy use of biomass primarily for household heating applications and power generation [6]. The general steps in utilizing biomass for solid fuel (briquette) production include sourcing, collection and transportation, drying, size reduction, and densification. Densification process involves the compaction of biomass with or without a binding agent under relatively high temperature and pressure to achieve higher energy per volume of the material. Densification generally increases the bulk density, improves the handling and logistics, reduces the labor costs, improves the thermal properties of biomass as well as the direct or co-combustion of biomass [7,8].

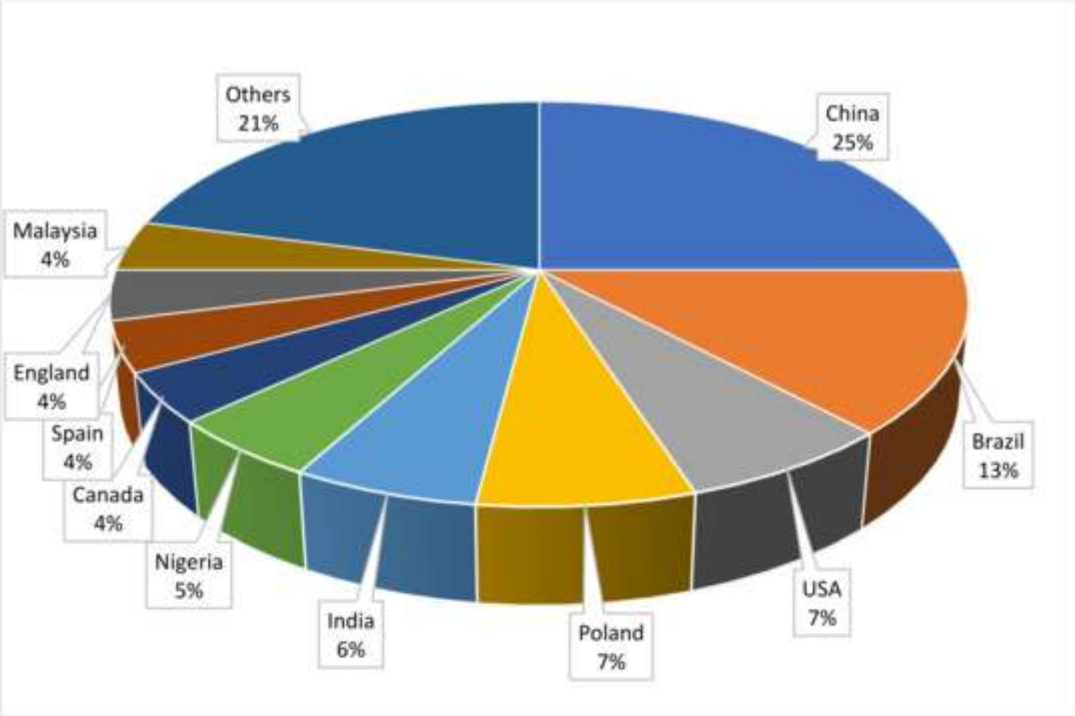
Densified biomass in the form of briquettes (Figure 1a) could take different shapes and sizes, including cylindrical, cubic, and rectangular, with or without a hole in the center [9]. A number of densification systems are employed in the production of briquettes and they include hydraulic piston presses, mechanical piston and ram presses, roller presses, manual presses, and screw extruders [10,11]. A detailed review of biomass briquette production processes and the various accompanying briquetting machines has recently been carried out [12]. While biomass pellets (Figure 1b) are also products of the densification process, they are relatively smaller compared to briquettes. They are usually cylindrical in shape with a diameter of between 3 and 27 mm and a length of between 3 and 31 mm [13]. Briquettes of cylindrical shape are generally between 18 and 55 mm in diameter and 10 and 100 mm in length [14,15]. However, there are generally no recognized standard dimensions distinguishing biomass pellets from briquettes [7].

(a) (b)

Energies 15 02426 g001 550Figure 1. (a) Sample of biomass briquettes and (b) biomass pellet samples.

In the past 10 years (2012 to 2021), the number of research publications focused on biomass briquetting has consistently been on the increase on a yearly basis, as identified in the online databases of Web of Science (Web of Science Core Collection. Available online: 2c437953/relevance/1 (accessed on 3 January 2022)) and Science Direct (Peer-reviewed journal articles search. Available online: https://www.sciencedirect.com/search (accessed on 3 January 2022)). In Web of Science, only 24 publications were identified in 2012, and the number rose to 105 in 2021; while in Science Direct, 143 articles were published in 2012, while 439 were published in 2021. This suggests a growing research interest in this area of study. A total of 10 countries account for more than 77% of the total publications (636) identified in the Web of Science database for the 10-year period under consideration and they include China, Brazil, USA, Poland, India, Nigeria, Canada, Spain, England, and Malaysia, in that order (Figure)

2). This data is based on the location of the authors of the publications.



Energies 15 02426 g002 550 Figure 2. Share of publications on biomass briquetting by the location of authors (2012–2021). Source: https://www.webofscience.com/ (accessed on 3 January 2022).

A number of studies have broadly reviewed different aspects of densification technology, including production processes and briquetting machines [12], devices used for the measurement of various solid fuel properties [7], biomass feedstock, processing characteristics, and the economics of densifying biomass [16], briquetting process variables and combustion [11], and the economics of biomass briquetting [17]. However, recent reviews on the current state of research on biomass briquette binders and briquette quality parameters is lacking in the literature. The main objective of this study is to review the current state of research on the use of binders in biomass briquette production, and briquette quality parameters with the focus on mechanical and handling properties. The briquette qualities considered in this study focus only on the mechanical and handling properties resulting from the briquetting process. It is noteworthy to state that this study did not consider combustion and emission quality factors and only recent literature spanning the period of 10 years from 2012 to 2021 were reviewed.

In this study, literature including journals, book chapters, PhD theses, and conference proceedings on biomass briquetting spanning a 10-year period from 2012–2021 were considered. Only literatures available in the English language or published in other languages but accompanied with an English translation were considered. The search for literature was conducted over the internet using online databases, including Google Scholar, Scopus, Web of Science, and Science Direct. The search was done using various combinations of key words relevant to the subject matter, such as biomass briquettes, biomass briquetting, biomass briquette and binders, biomass briquette and quality factors or parameters, biomass briquette and adoption or use, biomass briquettes and developing economies or countries. Non-biomass (e.g., coal) related papers were discarded. Based on title and abstract content, only literature that address biomass briquette binders, quality assessment, and briquette adoption or use in developing countries were selected and reviewed. Furthermore, bibliography in key selected documents were also examined with the aim of identifying other relevant papers.

Biomass generally refers to all biological materials derived from living organisms, including animal, and plant. Within the context of biomass briquetting, an example of biomass would include a wide range of materials, such as wood shavings from forest operations, agricultural residues from agro-processing activities, industrial wastes, animal, and domestic and municipal wastes. Figure 3 shows samples of biomass used for briquette production. The energy contained in biomass can be released through direct combustion or alternatively converted to other biofuels [18]. Biomass may be classified according to their origin as shown in Figure 4.

Energies 15 02426 g003 550Figure 3. Examples of biomass for briquette production (a) agro-processing residues—breadfruit shells, (b) wood fiber, and (c) forest residues—chips from tree branches and small-diameter trees.

The biomass materials are mostly organic remainder generated because of human activities (residual biomass including agroforestry residue, and industrial and municipal bio-wastes) or naturally grown in nature, e.g., energetic crops or naturally growing grasses. For biomass briquetting, vegetable- or plant-derived raw materials are the preferred densification material, while animal-derived biomass is often used as binding material, e.g., cow dung. The predominant use of vegetable or plant biomass sources could be attributed to its wide availability compared to animal derived biomass. Table 1 shows the global quantity of selected biomass from agricultural crops burnt in 2009 and 2019. This represents potential amount of biomass available for biomass briquetting with little or no alternative competitive use. For most of the crops, the amount of burnt biomass has continued to rise, especially in Africa, Asia, and South America. In addition to agroforestry residues, there has been a growing interest in the use of urban and industrial wastes for briquetting [19,20]. This could be attributed to the increasing rural–urban migration resulting in increased generation of industrial and municipal solid wastes. Urban and industrial wastes are expected to find more use in biomass briquetting, particularly in mixed-material briquetting, due to the increasing need to effectively manage such wastes in a sustainable manner.

Energies 15 02426 g004 550

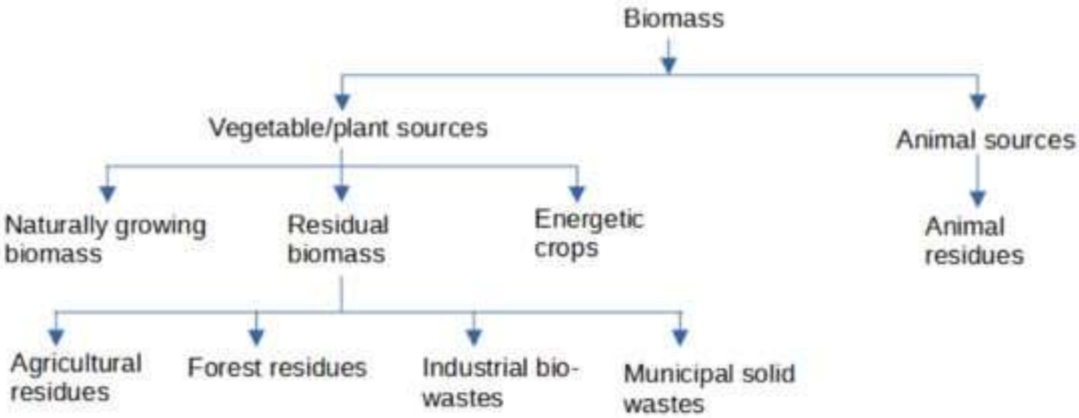


Table 1. Regional burnt biomass (dry matter, Mt).

Region	Year	Burnt Biomass Dry Matter (Mt)			
		Maize	Rice, Paddy	Sugar Cane	Wheat
Africa	2009	30.30	4.87	0.93	4.12
	2019	40.71	9.41	1.04	3.90
North America	2009	33.31	0.69	0.23	11.94
	2019	34.40	0.55	0.24	9.88
South America	2009	19.60	2.87	6.47	3.35
	2019	28.15	2.24	7.54	3.75
Asia	2009	53.48	76.94	6.31	40.44
	2019	66.47	76.23	7.13	39.46
Europe	2009	13.93	0.37	-	24.47
	2019	18.35	0.34	-	24.95
Oceania	2009	0.09	0.01	0.29	5.43
	2019	0.08	0.01	0.31	4.18

Figure 4. Classification of biomass based on the origin (adapted from [21]).

For commercial and sustainable production of fuel briquettes, suitable biomass feedstock must be available, easily collected, transported, and stored for further processing prior to compaction. Agricultural and forest biomass may be considered but they should be readily available in a sustainable manner. Concerns have been expressed on the potential competitive impact of the use of biomass for bioenergy purposes could have on other uses, including food and fodder [21]. The allocation of less fertile lands for the cultivation of energy crops through thought-out mechanisms, regulations, and cooperation among stakeholders have been suggested as means of mitigating against this [22]. Another major constraint in the commercial briquetting of biomass is within the context of supply chain management—the sustainable supply of biomass resource at cost-effective price and volume. This is influenced by a number of factors, including biomass structure, seasonal harvest, and the scattered geographical distribution of biomass that makes it difficult for their collection, transportation, and storage on a large scale [23]. The design of an efficient and effective biomass supply chain thus becomes critical in facilitating sustainable raw material preprocessing and supply for commercial briquetting [24,25]. However, in most developing countries, particularly in sub-Saharan Africa where domestic energy sources are still comprised mainly of firewood, there appears to be non-existence of any formal biomass supply chain structure.

In addition, concerns about raw material quality have also been expressed [26]. To address this, the use of composite raw materials has been explored in the production of briquettes [17,27,28]. This strategy aims to take advantage of differences in the structural and chemical characteristics of different biomass materials on the bonding strength and overall properties of the briquettes. Composite briquettes from materials with similar and compensating characteristics have been studied. Chungcharoen and Srisang [28] suggested the use of small cashew nut sizes in the briquetting of cashew and areca nuts in a composite ratio of 65% to 25%, respectively, to produce high-quality composite briquettes. Lubwama, et al. [29] demonstrated the benefits of producing composite briquette from rice husks, coffee husks, and groundnut shell over single constituent briquettes. The study reported improved heat transfer in composite briquette of coffee and rice husks without binders when placed sequentially in the briquette composition. Obi [30] suggests an optimum blending ratio of 50:50 for composite briquettes of palm kernel shell and sawdust feedstock. However, the increased addition of palm kernel shell reduced the weathering ability of the briquettes. Exploring opportunities in producing composite briquettes thus require further investigations particularly in identifying biomass materials that compensate their individual bonding and combustion properties

Author Contributions

1. Hoang, A.T.; Nguyen, X.P. Integrating renewable sources into energy system for smart city as a sagacious strategy towards clean and sustainable process. J. Clean. Prod. 2021, 305, 127161. [Google Scholar] [CrossRef]

2. Atabani, A.; Tyagi, V.K.; Fongaro, G.; Treichel, H.; Pugazhendhi, A.; Hoang, A.T. Integrated Biorefineries, Circular Bio-Economy, and Valorization of Organic Waste Streams with Respect to Bio-Products; Springer: Berlin/Heidelberg, Germany, 2021; p. 1. [Google Scholar]
3. Hoang, A.T.; Ong, H.C.; Fattah, I.R.; Chong, C.T.; Cheng, C.K.; Sakthivel, R.; Ok, Y.S. Progress on the lignocellulosic biomass pyrolysis for biofuel production toward environmental sustainability. Fuel Process. Technol. 2021, 223, 106997. [Google Scholar] [CrossRef]
4. Hoang, A.T. 2-methylfuran (mf) as a potential biofuel: A thorough review on the production pathway from biomass, combustion progress, and application in engines. Renew. Sustain. Energy Rev. 2021, 148, 111265. [Google Scholar] [CrossRef]
5. Carter, E.; Shan, M.; Zhong, Y.; Ding, W.; Zhang, Y.; Baumgartner, J.; Yang, X. Development of renewable, densified biomass for household energy in china. Energy Sustain. Dev. 2018, 46, 42–52. [Google Scholar] [CrossRef]
6. Gilvari, H.; de Jong, W.; Schott, D.L. Quality parameters relevant for densification of bio-materials: Measuring methods and affecting factors-a review. Biomass Bioenergy 2019, 120, 117–134. [Google Scholar] [CrossRef]
7. Chaney, J.; Clifford, M.; Wilson, R. On the heat pulse method for the determination of the thermal properties of biomass briquettes. Int. Rev. Mech. Eng. 2012, 6, 277–283. [Google Scholar]
8. Chaney, J.; Clifford, M.; Wilson, R. An experimental study of the combustion characteristics of low-density biomass briquettes. Biomass Mag. 2010, 1, 1–8. [Google Scholar]
9. Tumuluru, J.S.; Wright, C.T.; Hess, J.R.; Kenney, K.L. A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application. Biofuels Bioprod. Biorefin. 2011, 5, 683–707. [Google Scholar] [CrossRef]
10. Dinesha, P.; Kumar, S.; Rosen, M.A. Biomass briquettes as an alternative fuel: A comprehensive review. Energy Technol. 2019, 7, 1801011. [Google Scholar] [CrossRef]
11. Marreiro, H.M.; Peruchi, R.S.; Lopes, R.M.; Andersen, S.L.; Eliziário, S.A.; Rotella Junior, P. Empirical studies on biomass briquette production: A literature review. Energies 2021, 14, 8320. [Google Scholar] [CrossRef]
12. Jiang, L.; Yuan, X.; Xiao, Z.; Liang, J.; Li, H.; Cao, L.; Wang, H.; Chen, X.; Zeng, G. A comparative study of biomass pellet and biomass-sludge mixed pellet: Energy input and pellet properties. Energy Convers. Manag. 2016, 126, 509–515. [Google Scholar] [CrossRef]
13. Sengar, S.; Mohod, A.; Khandetod, Y.; Patil, S.; Chendake, A. Performance of briquetting machine for briquette fuel. Int. J. Energy Eng. 2012, 2, 28–34. [Google Scholar] [CrossRef][Green Version]
14. Kobilov KH. Abduraxmonov O.R., K.Z. Abidov.; Creation of new technology of coal briquette manufacturing. Sjif impakt faktor: 7.032epra international journal of multidisciplinary reserch (IJMR) 01.11.2020 P. 390-393.
15. Bajwa, D.S.; Peterson, T.; Sharma, N.; Shojaeiarani, J.; Bajwa, S.G. A review of densified solid biomass for energy production. Renew. Sustain. Energy Rev. 2018, 96, 296–305. [Google Scholar] [CrossRef]
16. Kpalo, S.Y.; Zainuddin, M.F.; Abd Manaf, L.; Roslan, A.M. Evaluation of hybrid briquettes from corncob and oil palm trunk bark in a domestic cooking application for rural communities in Nigeria. J. Clean. Prod. 2021, 284, 124745. [Google Scholar] [CrossRef]
17. Sahu, S.G.; Chakraborty, N.; Sarkar, P. Coal–biomass co-combustion: An overview. Renew. Sustain. Energy Rev. 2014, 39, 575–586. [Google Scholar] [CrossRef]
18. Tumuluru, J.S.; Yancey, N.A.; Kane, J.J. Pilot-scale grinding and briquetting studies on variable moisture content municipal solid waste bales–impact on physical properties, chemical composition, and calorific value. Waste Manag. 2021, 125, 316–327. [Google Scholar] [CrossRef]
19. Manirakiza, N.; Ndikumana, T.; Jung, C.G. Towards the promotion of fuel briquettes using municipal solid waste and residual biomass in Burundi. Int. J. Environ. 2020, 9, 14–31. [Google Scholar] [CrossRef][Green Version]

20. Roberts, J.J.; Cassula, A.M.; Prado, P.O.; Dias, R.A.; Balestieri, J.A.P. Assessment of dry residual biomass potential for use as alternative energy source in the party of general pueyrredón, argentina. Renew. Sustain. Energy Rev. 2015, 41, 568–583. [Google Scholar] [CrossRef]
21. Vávrová, K.; Knápek, J.; Weger, J. Modeling of biomass potential from agricultural land for energy utilization using high resolution spatial data with regard to food security scenarios. Renew. Sustain. Energy Rev. 2014, 35, 436–444. [Google Scholar] [CrossRef]
22. Liu, L.; Wang, D.; Gao, L.; Duan, R. Distributed heating/centralized monitoring mode of biomass briquette fuel in chinese northern rural areas. Renew. Energy 2020, 147, 1221–1230. [Google Scholar] [CrossRef]
23. Lin, T.; Rodríguez, L.F.; Davis, S.; Khanna, M.; Shastri, Y.; Grift, T.; Long, S.; Ting, K. Biomass feedstock preprocessing and long-distance transportation logistics. GCB Bioenergy 2016, 8, 160–170. [Google Scholar] [CrossRef]
24. Nunes, L.J.; Matias, J.C.; Loureiro, L.M.; Sá, L.C.; Silva, H.F.; Rodrigues, A.M.; Causer, T.P.; DeVallance, D.B.; Ciolkosz, D.E. Evaluation of the potential of agricultural waste recovery: Energy densification as a factor for residual biomass logistics optimization. Appl. Sci. 2021, 11, 20. [Google Scholar] [CrossRef]
25. Zakaria, I.H.; Ibrahim, J.A.; Othman, A.A. Introducing Briquette Storage System in Value Chain of Oil Palm Fiber Waste for Optimal Electricity Grid Supply: Biogas. In AIP Conference Proceedings; AIP Publishing LLC: Melville, NY, USA, 2018; p. 020156. [Google Scholar]
26. Rezania, S.; Din, M.F.M.; Kamaruddin, S.F.; Taib, S.M.; Singh, L.; Yong, E.L.; Dahalan, F.A. Evaluation of water hyacinth (eichhornia crassipes) as a potential raw material source for briquette production. Energy 2016, 111, 768–773. [Google Scholar] [CrossRef][Green Version]
27. Chungcharoen, T.; Srisang, N. Preparation and characterization of fuel briquettes made from dual agricultural waste: Cashew nut shells and areca nuts. J. Clean. Prod. 2020, 256, 120434. [Google Scholar] [CrossRef]
28. Lubwama, M.; Yiga, V.A.; Muhairwe, F.; Kihedu, J. Physical and combustion properties of agricultural residue bio-char bio-composite briquettes as sustainable domestic energy sources. Renew. Energy 2020, 148, 1002–1016. [Google Scholar] [CrossRef]
29. Obi, O.F. Evaluation of the physical properties of composite briquette of sawdust and palm kernel shell. Biomass Convers. Biorefin. 2015, 5, 271–277. [Google Scholar] [CrossRef]
30. Mani, S.; Sokhansanj, S.; Bi, X.; Turhollow, A. Economics of producing fuel pellets from biomass. Appl. Eng. Agric. 2006, 22, 421–426. [Google Scholar] [CrossRef]