RICE HUSK AND CHICKEN MANURE AS RAW MATERIALS FOR BIO-CHARCOAL BRIQUETTES FOR SUSTAINABLE ENERGY DEVELOPMENT

Sekam Padi dan Kotoran Ayam sebagai Bahan Baku Briket Bioarang untuk Pengembangan Energi Berkelanjutan

Agus Hadiarto[1], Muhammad Firdaus[2], I Made Jana Mejaya[3], Yayat Hidayat[1*]

[1]Research Center for Behavioral and Circular Economics, National Research and Innovation Agency
Jln. Jend. Gatot Subroto 10, Jakarta Selatan 12710, DKI Jakarta, Indonesia
[2]IPB University
Jln. Raya Dramaga Kampus IPB Dramaga Bogor 16680, West Java, Indonesia
[3]Indonesian Legumes and Tuber Crops Research Institute
Jln. Raya Kendalpayak No. 66, Kota Malang 65162, Jawa Timur, Indonesia
**Corresponding author. E-mail*: *yayathidayat1202@gmail.com*

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ABSTRAK

Pemanfaatan biomassa yang berasal dari sekam padi dan serasah unggas merupakan salah satu cara untuk memasok bahan baku sistem energi berkelanjutan yang lebih mudah, murah, dan melimpah. Tulisan ini bertujuan untuk mengestimasi potensi biomassa yang mengandung kotoran ayam dan sekam padi yang dapat dibentuk sebagai bahan bakar padat, yaitu briket bioarang. Briket biomassa yang berasal dari sekam padi dan kotoran ayam berpotensi untuk diolah menjadi briket bioarang melalui proses pirolisis. Artikel ini menyajikan tinjauan pustaka, potensi, dan prediksi biomassa sekam padi dan kotoran ayam berdasarkan data sekunder menggunakan metode ARIMA. Artikel ini menunjukkan dua metode estimasi sekam padi yang berbeda karena pada tahun 2018 Badan Pusat Statistik mengubah metode estimasi produksi padi yang digunakan sebelumnya dengan Metode Kerangka Sampel Area (KSA). Hasil kajian ini memprediksi bahwa ketersediaan sekam padi dan kotoran ayam akan terus meningkat. Prakiraan ini menunjukkan bahwa investasi untuk bisnis briket bioarang akan sangat prospektif karena ketersediaan sekam padi dan kotoran ayam yang sangat besar. Prospek ini juga didukung oleh peningkatan pendapatan nasional sebagai proksi dari peningkatan pendapatan rumah tangga. Permintaan bahan pangan pokok dan pangan hewani akan meningkat sehingga potensi bahan baku sekam padi dan kotoran ayam untuk pembuatan briket bioarang juga akan meningkat. Namun demikian, studi ini juga menunjukkan tantangan untuk mengembangkan bisnis briket bioarang seperti biaya investasi yang tinggi, ketidakpastian pasokan bahan baku, dan kurangnya kapasitas industri dan dukungan infrastruktur.

Kata kunci: *biomassa, briket bioarang, energi berkelanjutan, kotoran ayam, sekam padi*

ABSTRACT

Using biomass from rice husk and poultry litter is one way to supply easier, cheaper, and more abundant raw materials for a sustainable energy system. This paper aims to estimate the potential of biomass from chicken manure and rice husk for solid fuels, i.e., bio-charcoal briquettes. Rice husk and chicken manure can be processed into bio-charcoal briquettes through pyrolysis. This article presents the literature review, potential, and prediction of rice husk and chicken manure biomass based on the secondary data using ARIMA. This article shows two different estimation methods of rice husk because, in 2018, BPS-Statistics Indonesia changed the previous Method to the Area Sample Framework (KSA). This article predicts that the availability of rice husk and chicken manure will steadily increase, indicating that investment in the bio-charcoal briquette business would be very prospective. It is also supported by increased national income as a proxy of household income. Demand for staple and animal food will increase, implying that rice husk and chicken manure will also increase to produce bio-charcoal briquettes. This paper also points out the challenges in developing a bio-charcoal briquette business, such as high investment costs, uncertainty in the supply of raw materials, and a lack of industrial capacity and infrastructure.

Keywords: *bio-charcoal briquettes, biomass, chicken manure, rice husk, sustainable energy*

INTRODUCTION

A global society develops sustainable energy systems based on renewable energy raw materials (Agbor et al. 2011) that are more environmentally friendly, such as biomass, ocean, wave, tide, solar, and wind (Saidur et al. 2011; Asemokha et al. 2020). Biomass is a cheap and abundant raw material for the sustainable energy and chemical industry (Saidur et al. 2011; Bharathiraja et al. 2016; Al-Hamamre et al. 2017). Charcoal briquettes, one biomass type, have value and energy content equal to or even higher than coal (Basu et al. 2011). Charcoal briquettes can replace kerosene, whose consumption is increasing, followed by its limited availability (Miharja 2016).

The economic growth of the agricultural sector has had a negative effect in developing countries, which needs to be appropriately handled, such as the enhancement of farming residues. The major farming residues are derived from rice (*Oryza sativa*), wheat (*Tritium aestivum*), and maize (*Zea mays*) farming, which produce 3.2–4.5 ton crop residues per hectare (Sukhesh and Rao 2018).

Poultry litter is a mixture of chicken manure containing excreted enteric bacteria and other organic materials such as feathers and bedding materials. It is a type of biomass with a value-added, is environmentally beneficial, and is a potential raw material for bioenergy by recycling organic waste (Bernhart et al. 2010; Qiu and Guo 2010).

Solid biomass sources, called solid fuels, comprise firewood, forest wood, coal, and charcoal (Mulukutla et al. 2020). In many countries, households in rural and suburban areas still use wood fuel and charcoal as the main energy sources (FAO 2010). In addition, about 68% of the population in Asian countries that still live in rural areas usually use this solid biomass for cookstoves and heaters in the kitchen (Mulukutla et al. 2020). However, many developing countries have recently improved cookstoves using solid fuels and carbon conversion to reduce emissions inside their houses (Mulukutla et al. 2020; Sharma et al. 2020). On the other side, liquid biofuels have been promoted as alternative energy to enhance total fuel capacity worldwide, which may also reduce greenhouse-gas emissions. However, the use of raw materials for liquid fuel can negatively affect the achievement of food security (FAO 2010).

Poultry litter and crop residues have the potential to be alternative energy as solid fuels, a friendly environment, and without interfering with food security goals. Moreover, some countries have challenges creating solid fuels derived from biomass. Some previous studies discussed in term of charcoal briquettes. Miharja (2016) showed the potential of briquettes as a quality alternative energy according to the Indonesian national standard (SNI). Some studies on charcoal briquettes used for cookstoves have also been conducted, and one of them revealed that charcoal briquettes could be produced from biomass of high-density wood. Briquettes will be shaped if the raw material contains a high density of material structure (Sunardi et al. 2019). In comparison, biomass such as crop residue and poultry manure contains low-density material (Mulukutla et al. 2020). Therefore, making briquettes using raw materials from crop residue and poultry manure is challenging.

However, there are still limited studies that reveal the potential biomass for making charcoal briquettes and predict the potential of chicken manure and rice husk as raw materials for bio-charcoal briquettes. Therefore, his paper aims to reveal how potential raw materials of chicken manure and rice husk biomass can be utilized as solid fuels, i.e., bio-charcoal briquettes.

METHODOLOGY

This article provides an overview of the literature review regarding sustainable energy derived from biomass, especially rice husk and chicken manure. The biomass has the potential to be processed into bio-charcoal briquettes. It is then combined with the secondary data showing the potential of rice husk and chicken manure in Indonesia as well as animal and staple food consumption data. Finally, those data are forecasted using the Autoregressive Integrated Moving Average (ARIMA) model.

ARIMA augments the previous model, ARMA, by developing data series to achieve a stationary through first differencing to integrate order one (Verbeek 2017). Many researchers' work has been done to build the model using the (ARIMA) to forecast the potential commodity, such as the raw material to be used as a value-added product (Fattah et al. 2018; Siregar et al. 2018; Hankla and Boonsothonsatit 2020; Verano et al. 2020). Following the previous study to construct the ARIMA technique, this study comprises four main steps: identifying test patterns, estimating the parameters, identifying the adequacy of the model, and forecasting the model (Tlegenova 2015)

RESULTS AND DISCUSSION

The Potential of Biomass

The global society recently has the mandate to improve renewable energy raw materials as secure and sustainable energy systems (Agbor et al. 2011). They undertake to shift the fossil-fuel energy causing global warming, acid rain, and urban smog toward more environmentally friendly substances such as biomass, ocean, solar, wave, tide, and wind. It will reduce carbon emissions by up to 80% (Saidur et al. 2011; Asemokha et al. 2020). Biomass is available and easy to obtain for energy and chemical production sustainably (Saidur et al. 2011) and is cheap and abundant worldwide (Bharathiraja et al. 2016; Al-Hamamre et al. 2017).

The major energy source is derived from the fossil substances used for 90% of power generation, and the remaining 10% is used for chemical synthesis (Bharathiraja et al. 2016). Biomass may fulfill the energy demand of about 10% of the world. The primary biomass utilization is for heating, generating power, biofuel of vehicles, and chemical synthesis (Al-Shemmeri et al. 2015; Bharathiraja et al. 2016).

In general, biomass resources could produce energy from urban organic waste, farming residues, and livestock manure, as much as 40.1%, 25.5%, and 12.5%, respectively (Al-Hamamre et al. 2017). In addition, this biomass contains low sulfur, so it will provide a low cost for the processing industry, although its moisture content is still high. The highest moisture content is found in poultry litter, 7–49% (Bernhart et al. 2010; Al-Hamamre et al. 2017).

As a renewable source, farming residues contain lignocellulosic biomass comprising two carbohydrate polymers and a non-carbohydrate polymer with few proteins and fats. Those carbohydrates, namely polysaccharides, are composed of cellulose (30–44%) and hemicellulose (16–50%). Meanwhile, non-carbohydrate polymers or aromatic polymers are composed of lignin (7–23%), as shown in Table 1 (Abdel-Hamid et al. 2013; Sukhesh and Rao 2018; Zoghlami and Paës 2019). In partial, rice straw as a crop residue contains 47.8% nitrogen, 0.1% carbon, and 14.7% ashes (Ríos-badr 2020).

The farming residues are estimated to contain an energy potential of 4.15 EJ, while animal manure has a calorific value of about 13.50–17.80 MJ/kg (Al-Hamamre et al. 2017; Sukhesh and Rao 2018). Specifically, the manure from cattle and poultry comprises 90% of animal manure because the private sector farms collect those manure with good management (Al-Hamamre et al. 2017).

Poultry produces manure of about 0.15 kg/head/day in general. The manure contains crude fiber (30.63–32.65%), crude protein (9.97–12.67%), nitrogen (1.7%), phosphorus (0.16%), and potassium (0.58%) (Saparudin et al. 2015; Rifai et al. 2018) while husk contains crude fiber (35.68%) and basic carbohydrates (33.37%). Both have lots of cellulose carbohydrates and fiber, which are important for producing briquettes (Saparudin et al. 2015).

Due to high carbon and crude fiber, biomass from rice husks and poultry manure is highly likely to be processed into solid fuels such as briquettes. The biomass briquettes can further be processed into bio-charcoal briquettes through pyrolysis. (Saparudin et al. 2015).

The Potential of Rice Husk in Indonesia

Rice generates the highest residue among the food crops, about 154 Mt/year, resulting in 43.5 Mt/year of surplus residue after its primary use as animal feeding (Sukhesh and Rao 2018). The rice husks contain nitrogen, carbon, and ashes (47.8, 0.1%, and 14.7%, respectively) (Ríos-badr 2020). Therefore, it is estimated that 34.9–49.1 Mt of crop residues in Indonesia (BPS 2020a) are generated annually, and about 25–34% of generated residues can be considered surplus quantity.

Table 1. The main-crop residues containing lignocellulosic biomass

Crop residue	Cellulose (%)	Hemicellulose (%)	Lignin (%)	C/N ratio
Rice straw	34.9	16.7	23.3	47.0
Wheat straw	38.6	25.1	7.3	-
Maize straw	38.8	29.5	7.1	34.9

Source: Sukhesh and Rao (2018)

It is estimated that Indonesia generates about 34.9–49.1 Mt of farming residues (BPS 2018b) and contributes a surplus of as much as 25–34% yearly. Furthermore, the highest residue is derived from rice, about 154 Mt/year, and contributes a surplus quantity of as much as 443.5 Mt/year, mainly utilized for cattle feed (Sukhesh and Rao 2018).

Paddy is harvested as the primary crop. For every one-kilogram paddy harvested, it is estimated that the field would result in about 0.41–3.96 kg of rice straw and 0.20–0.33 kg of rice husk. While rice husk, included as a type of biomass, is the main product produced by the rice milling industry (Ríos-badr 2020). If Indonesia had 56,537,774 tons of paddy in 2018 (BPS 2018b), it is predicted that rice husks would be produced at about 11.30–18.66 Mt.

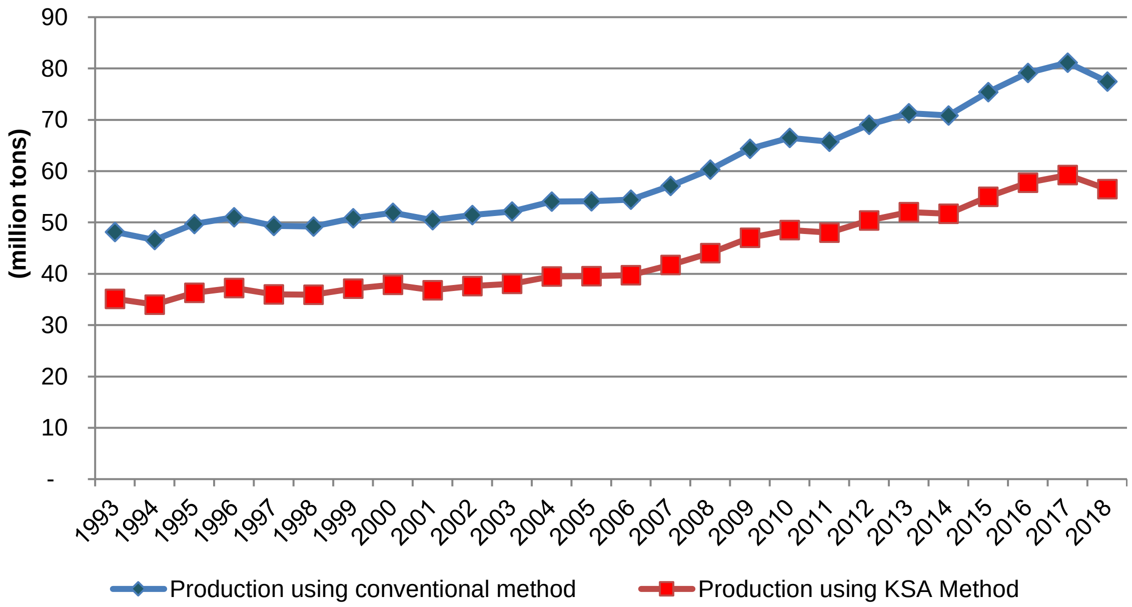
BPS-Statistics Indonesia has used the Area Sample Framework (KSA) method to calculate rice harvested area, production, and productivity since 2018. The method uses a direct observation approach to land area units based on Geographic Information System (GIS) technology, remote sensing, information technology, and statistics. Meanwhile, the previous (conventional) method uses a list of agricultural statistics obtained from the eyes of data collectors (eye estimate), so rice production data using KSA has a higher level of accuracy. The calculation results with the KSA method differ from the conventional method by 27% (BPS 2018a; BPS Tarakan 2022).

Figure 1 shows rice production data in Indonesia in the 1993–2017 period using the conventional method. Nevertheless, it would be potentially fallacious to predict rice production. Therefore, this paper corrects production data during the period by decreasing it by 27%, and the data are named to become rice production using the KSA method. This paper uses the KSA method to obtain accurate predictions for the availability of rice husks in Indonesia for the next ten years.

Rice production using the KSA method increased during 1993–2008 with a growth rate of 1.97%, and the growth rate during 2009–2018 was higher (2.59%). In addition, rice production growth increased sharply (9.32%) in the 2014–2018 period, from 51,7 million to 56,5 million tons.

This analysis assumes that paddy weight contains at least 20% rice husk (Ríos-badr 2020). Therefore, this study may predict (using the ARIMA forecasting method) the raw material of bio-charcoal briquettes for ten years later from rice husk in Table 2.

Table 2 shows that rice husk can be obtained at least 11.5 tons in 2019 and 13.2 tons in 2028. It predicts that rice husk production will increase steadily by 1.54% each year (Figure 2). This by-product is more abundant than the chicken by-products (chicken manure), reaching 0.37 tons in 2028 (Table 4 below). The briquettes need rice husk and chicken manure in a similar composition. However, rice husk can be made into briquettes without chicken manure.



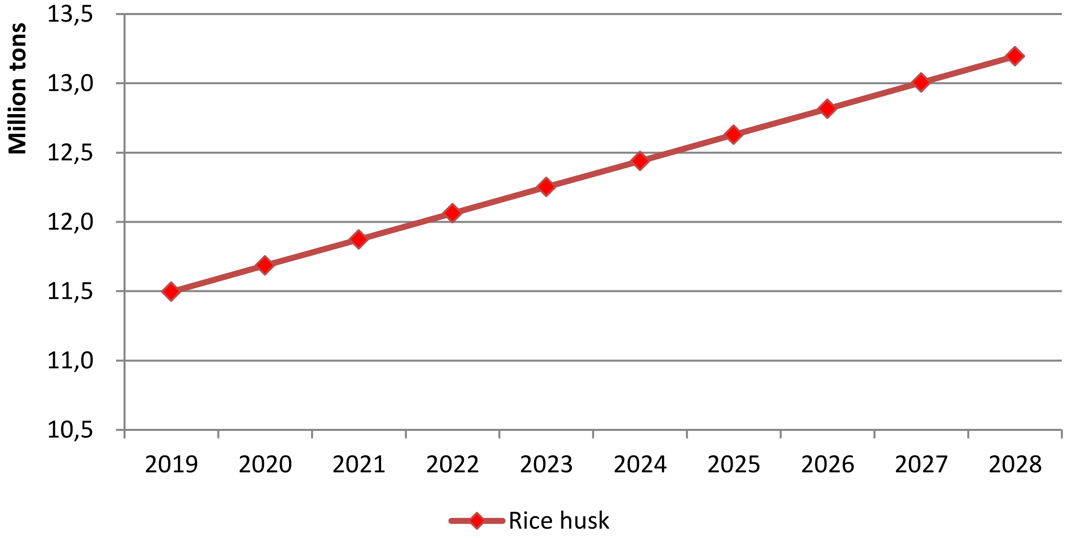
Source: BPS (2020a)

Figure 1. Rice production in Indonesia, 1993–2018

Table 2. Forecasting of rice production and rice husk in Indonesia, 2019 – 2028

Year	Rice production (tons)	Rice husk (tons)
2019	57,481,335	11,496,267.0
2020	58,424,895	11,684,979.0
2021	59,368,456	11,873,691.2
2022	60,312,017	12,062,403.4
2023	61,255,578	12,251,115.6
2024	62,199,138	12,439,827.6
2025	63,142,699	12,628,539.8
2026	64,086,260	12,817,252.0
2027	65,029,820	13,005,964.0
2028	65,973,381	13,194,676.2

Source: Forecasting data BPS (2020a) using KSA method



Source: Forecasting data BPS (2020a) using KSA method

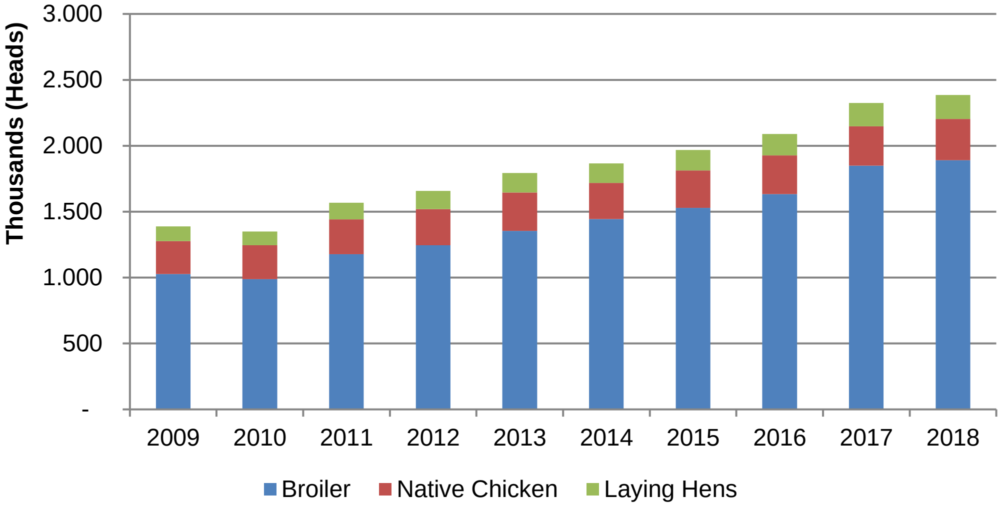
Figure 2. Forecasting of rice husk in Indonesia, 2019–2028

The Potential of Chicken Manure in Indonesia

The average population of chickens during the last ten years (2009–2018) was 1,838,684 birds, consisting of 1,413,558 (77.9%) broilers, 280,228 (15.24%) native chickens, and 144,898 (7.88%) layers (Figure 3). The broiler population increased sharply compared to the other types of chicken.

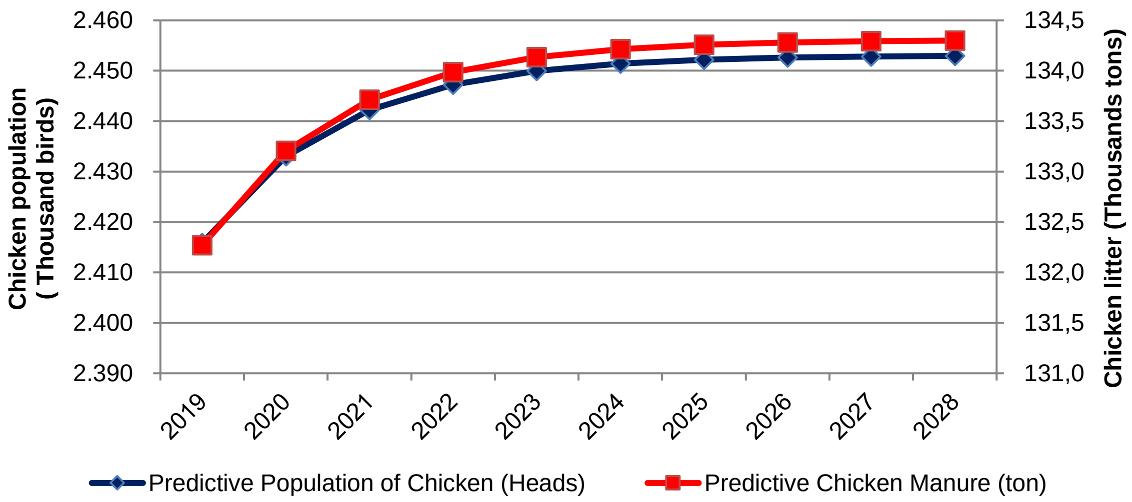
The chicken population in 2009 was only 1,387,760 birds and has increased over the past ten years to 2,384,147 birds, with an average growth rate of 6.3% per year. The most rapid population growth occurred in 2011 (16.1%) and 2017 (11.3%). Based on those figures, this paper predicts the population of chickens in Indonesia. Furthermore, the chicken population data is used to calculate the amount of chicken litter as a raw material for briquettes. The ARIMA forecasting method) was used to predict the chicken manure produced in the following ten years, as shown in Table 3 and Figure 4.

This study predicts that the chicken population will increase to 2,452,954 birds in 2028, and we may calculate the amount of chicken manure as a raw material for bio-



Source: Ditjen PKH (2013, 2018)

Figure 3. Production of three types of chicken in Indonesia, 2009 – 2018



Source: Ditjen PKH (2013, 2018)

Figure 4. Prediction of chicken population and chicken manure production in Indonesia, 2019–2028

charcoal briquettes. We may predict that chicken manure will also increase in the coming ten years. Based on the previous study that chicken produces manure of about 0.15 kg/bird/day on average (Saparudin et al. 2015; Rifai et al. 2018), we predict that chicken manure produced in 2028 will reach 134,299 tons.

The Consumption of Animal Food and Staple Food

Based on National Socioeconomic Survey (Susenas) data (BPS 2020a) in Table 4, the average animal food expenditure increased over the 2018–2020 period, from 23,006 to 26,441 IDR/cap/month. In addition, the average level of food consumption derived from grains increased from 11,292 to 11,654 IDR/cap/month, while processed food rose from 189,223 to 206,736 IDR/cap/month.

The highest income of households will increase consumption of non-staple and animal-based foods, such as fruits. However, the number of low and medium-income households is much more than high-income households. Thus, in the aggregate expenditure of GDP, increased household expenditures indicate increased staple food and animal food consumption.

Table 3. The actual population of chicken, 2009–2018, and predicted chicken population and chicken manure production in Indonesia, 2019–2028

Year	Actual chicken population (birds)	Year	Predicted chicken population (birds)	Predicted chicken manure (tons)
2009	1,387,760	2019	2,415,877	132,269
2010	1,349,626	2020	2,433,006	133,207
2011	1,566,967	2021	2,442,252	133,713
2012	1,657,684	2022	2,447,244	133,987
2013	1,793,022	2023	2,449,938	134,134
2014	1,865,125	2024	2,451,393	134,214
2015	1,968,640	2025	2,452,178	134,257
2016	2,088,498	2026	2,452,602	134,280
2017	2,325,369	2027	2,452,831	134,292
2018	2,384,147	2028	2,452,954	134,299

Source: Ditjen PKH (2013, 2018)

Table 4. Household expenditures on food in Indonesia, 2018–2020 (IDR/cap/month)

Food expenditure	2018	2019	2020
Processed food	189,223	201,107	206,736
Animal food	23,006	24,783	26,441
Cereals	11,292	11,273	11,654
Vegetables	39,664	37,898	45,393
Fruits	28,486	27,444	30,116
Tubers	5,623	5,886	6,361

Source: BPS (2020a)

The consumption level of Indonesian people toward animal and staple food steadily increases though its price also increases yearly. However, it is accompanied by an increase in income (Ariani et al. 2018). Therefore, the consumption level of staple and animal food is also in accordance with the rate of household consumption in aggregate, as depicted in Figure 5 (BPS 2020b).

Animal food comes from livestock and fishery products. Livestock products comprise meat, eggs, and milk, while fishery products include fish, shrimp, squid, and shells. The types of animal food from livestock contain 29 items, while animal food from fishery products consists of 32 items (BPS 2014).

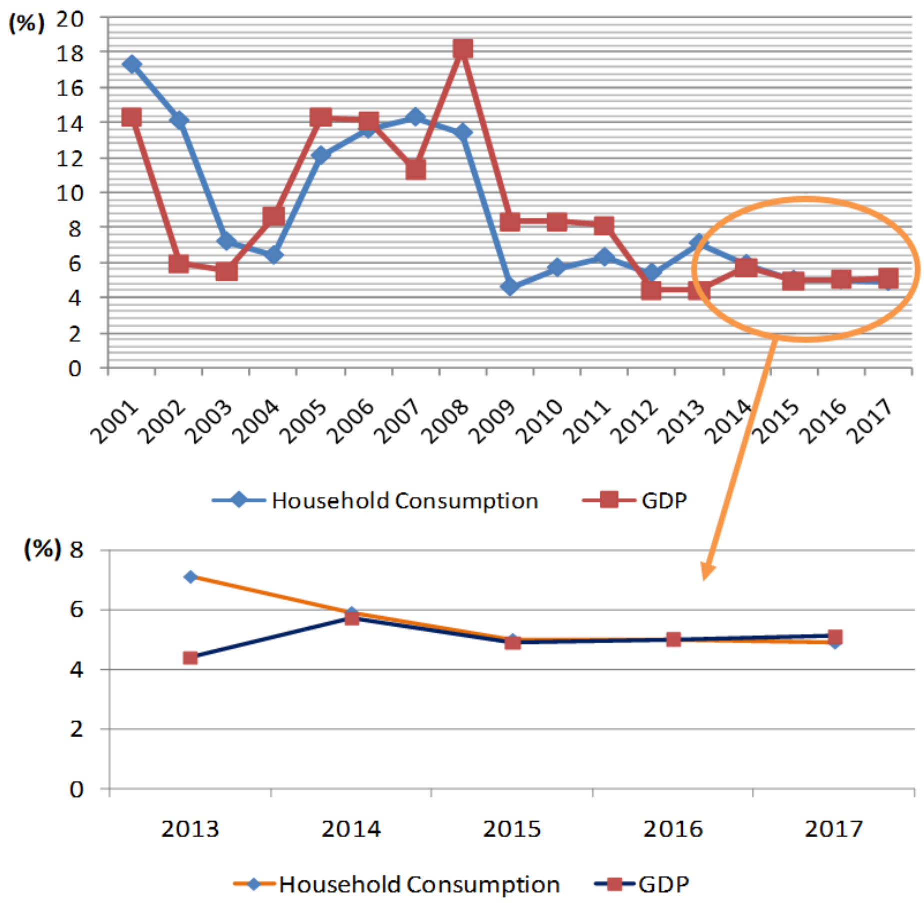
Animal food is an essential nutrient needed by the human body after staple food. Most Indonesian consume animal foods derived from fresh fish, eggs, and chicken meat (14.64, 6.61, and 4.11 kg/cap/year, respectively) (BPS 2014). However, the consumption of poultry meat is only 3.5 kg/cap/year, lower than other ASEAN countries such as Malaysia, Thailand, and the Philippines, 36.7 kg, 13.5, and 7.6 kg, respectively (Ariani et al. 2018). Nevertheless, if multiplied by the population, Indonesia has enormous consumption in ASEAN.

The Characteristics and Development Challenges of Bio-charcoal Briquettes

The Characteristics of Bio-charcoal Briquettes

Biomass has characteristics such as low bulk and energy density, high moisture, and irregular size and shape (Marreiro et al. 2021). For example, poultry litter is a low-density material of less than 500 kg/m3 (Bernhart et al. 2010). On the other hand, cookstoves require high-density fuel (850 kg/m3) in the form of briquettes (Mulukutla et al. 2020). Therefore, poultry litter and rice husk biomass should be processed into bio-charcoal briquettes to adjust to the cookstove requirement.

Due to its high carbon and crude fiber, biomass from rice husks and poultry manure is highly potential to be processed into solid fuels



Source: BPS (2020b)

Figure 5. Household consumption growth in GDP of Indonesia 2001–2017

such as briquettes. Chicken manure contains crude fiber (30.63–32.65%), crude protein (9.97–12.67%), nitrogen (1.7%), phosphorus (0.16%), and potassium (0.58%) (Saparudin et al. 2015; Rifai et al. 2018), while rice husk contains crude fiber (35.68%) and basic carbohydrates (33.37%). Both have lots of cellulose carbohydrates and fiber, which are important for producing briquettes (Saparudin et al. 2015).

Biomass can be augmented as an alternative fuel energy source by converting it into bio-charcoal briquettes, which have a higher heating value than ordinary biomass, through the pyrolysis process (Saparudin et al. 2015; Rifai et al. 2018). Pyrolysis is the gasification or combustion of biomass and can be defined as thermal degradation (de-volatilization) in an airtight room at 200–600 °C. It produces char, tar, and limited gas of CO and CO_2.

Rice husks and poultry litter as raw materials of this process are mixed by a composition of 1:1. It is then added adhesive starch and formed by a block tool. The raw material will decompose in the first stage at a temperature of 203–218 ^{o}C to 320–350 ^{o}C. The first stage of the reaction zone is rapidly processed because of the volatile character of the product. As a result, it needs only 16.17 and 17.59 degradation rates per minute for 1% and 8.21% of raw material, respectively. Additionally, the temperature for cellulose degradation reaches 320 to 400 ^{o}C until a maximum temperature of 328.94 to 321.83 ^{o}C for complete decomposition, respectively (Ríos-badr 2020). Briquette quality can be determined by calorific value, water content, specific gravity, ash content, fixed carbon, and volatile matter (Saparudin et al. 2015).

The Challenges of Bio-charcoal Briquette Development

This paper demonstrates the challenges of developing a bio-charcoal briquette business based on biomass energy. It needs high investment costs and faces uncertainty in the supply of raw materials because of seasonal characteristics and the lack of infrastructure of biomass systems in some countries. Thus, these obstacles should be overcome to achieve the feasibility of the business of bio-charcoal of briquettes for providing alternative energy (Al-Hamamre et al. 2017).

Some developing countries have coped with those obstacles by providing biomass resources (urban bio-waste, farming residue, and cattle manure). Nevertheless, those countries have established few industries for the combustion process that are only used for room heating. Additionally, the capacity of the biomass industry is still rarely achieved (Al-Hamamre et al. 2017).

Another challenge in developing bio-charcoal for the briquette business is the lack of raw material supply derived from farming residue because the abundant farming residues are not collected in the field or have been burned or completely abandoned. Moreover, the costs of handling farming residues and transportation are so high.

Biomass energy from poultry litter has the potential to be developed because it is supported by poultry farms that can collect poultry litter and achieve a 90% collection efficiency. However, poultry litter includes low-density bulk, which requires a high cost to transport from poultry farms to biomass industry areas (Bernhart et al. 2010; Al-Hamamre et al. 2017).

The government and society may cope with these challenges. The government may realize the business environment of bio-charcoal briquettes through at least four programs involving financial incentives for industry, infrastructure, education, training, and research and development of bio-charcoal briquettes. Society may build the industry to respond to bio-charcoal briquette business opportunities and eventually support national income.

CONCLUSIONS AND POLICY IMPLICATIONS

Conclusions

Based on this analysis, the main conclusion is that the prospect of the bio-charcoal briquette business is excellent. This is because the availability of raw materials, namely rice husk and chicken manure, is enormous and predicted to increase yearly.

The prospect of a bio-charcoal briquette business is supported by the projected increase in national income by 5% annually for the coming years. This increase will raise the household expenditure (consumption) on staple and animal food and, finally, increase the availability of rice husk and chicken manure as raw materials for bio-charcoal briquettes. However, some obstacles need to address appropriately to reach the feasibility of the bio-charcoal briquette business.

Policy Implications

The potential benefit of bio-charcoal briquettes from rice husk and chicken manure requires widespread implication to actualize the commercial environment in which the government has the role of creating a policy for accelerating the production of bio-charcoal briquettes at a commercial scale. The government may provide a supportive business environment for bio-charcoal briquettes through financial incentives for industry, infrastructure, and education and training. Research on bio-charcoal briquettes should also be intensified.

The government may encourage new entrepreneurs by providing financial incentives such as subsidy programs and easy access to financial institutions. New entrepreneurs also can occur when the government provides a good infrastructure supporting the bio-charcoal briquette industry, such as roads, water, and electricity. Furthermore, the government may support education and training programs, especially for young entrepreneurs entering the business environment. Eventually, research and development are primary for building the bio-charcoal briquette business environment. The study may find a new product with high efficiency and high quality to attract consumers' attention and expand market demand. However, this implication does not mean without society using this product. So, the community should be educated and introduced to the benefits of bio-charcoal briquettes for better living.

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