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Profitability Analysis of Developed Briquette Suitable for Energy Generation from Residue of Cattle Feed Sorghum Stalk and Groundnut Husk

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Abstract
The world's energy is dominated by technology that uses fossil fuels to generate electricity, chemicals, and materials. On the other side, the usage of conventional energies has resulted in massive environmental damage and climate change. This study looks into the development of briquettes from sorghum stalks and groundnut husks utilizing cow dung as a binder for fuel production using the low-pressure compaction method, which is an important source of renewable energy. The briquettes were labeled with cow dung binder compositions (5% to 25%), ratios (75% to 95%), and particle sizes ranging from 1 to 3 mm. The raw material was collected, cleaned, sun-dried, carbonized, and processed using a mortar grinder. DOE software, excel, and ANOVA were used to do numerical and graphical analyses of the data. After briquetting, the moisture content was 3.16%, fixed carbon 13.04%, volatile matter 80.20%, and ash 3.6%. The briquette had 51.56% carbon, 6.302% hydrogen, 0.0042% nitrogen, 42.134% oxygen, and 0.00093% sulfur. The calorific value of mixed briquettes varies from 20.08 to 24.36 MJ/kg. The maximum calorific value was achieved with a particle size of 1 mm and a 25% cow dung binder content, as a minimal particle size was preferred. According to the analysis, the created briquettes were smokeless, low in Ash content, and had a high Calorific value for burning above 17 MJ/kg for industrial driving and above 13 MJ/kg for residential usage. The development of briquetting technology leads to increased job prospects, decreased greenhouse gas emissions, and the establishment of entrepreneurs.

Keywords: Briquette, Groundnut Husk, Proximate Analysis, Sorghum Stalk, Ultimate Analysis

Introduction

Background and Justification of the Study

The worldwide requirements for energy have increased significantly over the last century as the world's population has grown. This results from the swiftly increasing population, global economic growth, urbanization, and the emergence of energy-dependent services [1]. The energy crisis is widely regarded as the primary issue of the new era [2]. The global market is dominated by technologies that use fossil fuels (petroleum, coal, and natural gas) to generate fuels, electricity, chemicals, and materials. While the usage of conventional energy sources such as oil, coal, and electricity has expanded intensively. Since the reduction of fossil fuels and air pollution has become a global issue, scientists are increasingly turning to biomass sources as an alternative fuel [3]. The International Energy Agency (IEA) predicts that worldwide energy consumption will increase by around 34% between 2012 and 2035. Conventional non-renewable energy (gas, oil, coal) is the primary source of energy in the world; it accounts for more than two-thirds of global energy consumption, with 34% oil, 27% coal, and 24% natural gas, followed by hydro at 7%, nuclear at 4%, and renewables (solar, wind, geothermal, biomass, etc.) at 4% [4] .

Higher living standards and population growth have resulted in increased demand for food and new forms of clean energy around the world. Energy is a vital element of human development and survival. Among the biggest challenges today are energy security, the environmental impact of fossil fuel consumption, and deforestation. [3]. The goal of any modern energy system must be to maximize profits with minimum inputs, application and selection of suitable plant materials and processes, optimum use of land, water, and fertilizer, creating an adequate arrangement, and strong research and development. [4].

To meet the ever-increasing need for energy, many studies are being conducted to develop alternative sources of energy that can replace or reduce the reliance on traditional sources of energy while simultaneously addressing environmental concerns to some extent. Biomass is in high demand due to its long-term sustainability. Clearly stated, biomass is stored energy [5].

Biomass is the world's third principal energy source, after coal and oil, and it is poised to make a large contribution to the global energy mix. Biomass refers to non-fossil, biodegradable organic material of plant, animal, and microbial origin [6]. It is organic material derived from plants and animals that serves as a renewable energy source. The energy produced from biomass refers to any organic substance utilized as fuel, including firewood, dung/manure, forest refuse, agricultural residues, and vegetable matter. Biomass materials include products, by-products, residues, and wastes from agricultural and forestry activities; non-fossil and biodegradable fractions from municipal and industrial wastes [7]. Typical examples include trees, grasses, agricultural products and wastes, wood waste and its derivatives, bagasse, MSW, waste paper, waste from food processing, aquatic plants and algae, and animal wastes [8].

Most developing nations, including Ethiopia, employ biomass energy sources that are generally outdated, resulting in indoor air pollution, which causes health and environmental problems. Ethiopia relies mostly on traditional biomass burning for more than 85% of its energy usage.

This has had numerous environmental and socioeconomic consequences [9]. Globally, 41% of homes and over 2.8 billion people rely on solid fuels (coal and firewood) for cooking and warmth. Cooking fuels are associated with health, land use and cover change, and climate change. This frequently results in the unselective and free felling of trees, the various portions of which are then dried and processed into fuelwood and charcoal. Such actions cause deforestation and other negative consequences for the ecosystem [10].

Energy is a prerequisite for the growth of any civilization. Nigeria, as well as India, China, Brazil, and Ethiopia, was among the largest wood fuel producers in 2019 [11]. In Ethiopia, the majority of home uses, such as cooking, baking, and lighting, rely on biomass; the most prevalent types are charcoal, firewood, leaves, agricultural leftovers, and animal dung. The available biomass resources, such as agricultural wastes, agro-industrial residues, and municipal waste, which are projected to meet the country's expanding energy need, can present a tremendous opportunity for acceptance of the briquette technology [12]. Biomass has historically served as a cheap and available source of fuel for the Ethiopian people, but this is undetermined to endure as a high need, resulting in resource decline as human populations and competing demands grow [13].

Agricultural wastes contain a lot of energy that can be recycled and processed into helpful goods, or used directly by burning them to produce heat, or indirectly by converting them to other biomass fuels [14]. Agricultural biomass wastes can be converted into energy that considerably replaces fossil fuels, reduces greenhouse gas emissions, and provides renewable energy to people in developing nations who still lack access to power [15]. Sustainable biomass energy, in its broadest sense, can be defined as energy that provides inexpensive, available, and reliable energy services that meet economic, social, and environmental needs [16]. These biomass energy sources have enormous potential; particularly those derived from agricultural wastes such as rice husks, straw, bagasse, maize stalks, groundnut husk, sorghum stalks and cobs, and others. Biomass derived from agricultural waste is frequently classified as useless material, resulting in the trash being disposed of in landfills or burned. These wastes have the potential to be used as alternative fuels like briquettes [3, 4].

Briquette is a relatively new technology for underdeveloped countries. There are various briquetting processes commercially available that are acceptable for the local market [12]. Briquettes have replaced the place for conventional and nonrenewable fuels such as coal, wood, fossil fuels, and others. Most rural villages lack access to power, and the cost of electricity is expensive for rural people [2]. Rural populations have traditionally not relied on commercial sources of energy, instead using biomass-based fuels such as fuel wood, animal dung, and crop leftovers. These are burned in primitive mud stoves at very poor thermal efficiency and over a lengthy period of time for one function [17].

Many countries have widely exploited the method of compacting bulky flammable materials to produce gasoline. Several studies have been conducted on the manufacturing of fuel briquettes for both domestic cooking and industrial applications using garbage. This volume of garbage can be transformed into a huge amount of energy and raw resources [18]. Typically, agricultural biomass wastes converted to energy may significantly displace fossil fuels, reduce greenhouse gas emissions, and offer sustainable energy to people in impoverished nations, including Ethiopia [19]. Rural communities have always relied on non-commercial energy sources. The majority of their home needs are satisfied by renewable sources of energy such as fuel wood and the products, byproducts, and residues of crop cultivation and animal-raising systems [12].

Ethiopia is the leading country in using wood as fuel, ranking among the top 10 tree cutters in the world [20]. The use of wood as a fuel stimulates tree cutting and felling (deforestation). This leads to desertification in Ethiopia, as well as flooding, soil erosion, and a loss of top soil fertility, particularly in the south. In rare situations, it can result in the disappearance of wildlife [21]. Therefore, this study focuses on alternative fuels to assess the practicality of agricultural byproducts such as sorghum stalks and groundnut husk, which are produced as trash in Ethiopian rural areas. As a result, the development of appropriate briquettes from chosen agronomic wastes as an alternative fuel for both rural and urban areas is required [22].

More than 80% of Ethiopia's population lives in rural areas without access to power. Firewood has long been the predominant cooking fuel in Ethiopia due to its low cost and easily availability. Domestic activities account for roughly 75% of the overall energy consumption from wood in rural areas. There aren't any professional wood charcoal producers [23]. Most Ethiopian farmers collect wood charcoal to generate revenue during the off-season. They use a single kiln to create an average of 100 kg of wood charcoal. If they collect 12 times a year on a part-time basis, they will have 1200 kg of wood charcoal every year [24].

But, utilizing firewood has implications for deforestation, health problems, and environmental pollution due to smoking and the release of CO2 and other greenhouse gases into the atmosphere. The goal of this research is to create a biomass briquette as an alternative fuel to fire wood by converting agricultural wastes (a leftover after cattle feed, sorghum stalk, and groundnut husk with binders) into smokeless energy, it providing supply of cheap fuel that burns cleanly [15].

Therefore, biomass briquette is an important part of domestic energy mix both for developed and developing countries towards achieving sustainable energy for heating applications, reducing environmental impact, economic benefits, reducing over dependence on fossil fuel, improving quality of rural and urban life, and for the production of various biofuels [4].

As raw materials, agro biomass wastes have attractive potentials for large-scale industries and community-level inventiveness. Most of the agricultural wastes are used in production of briquettes which are eco-friendly renewable source of energy and avoid adding fossil carbon to the atmosphere. Objective of the study was to analyze the calorific value of briquettes, which may help to use of agricultural wastes in proper way. Biomass briquetting production may be the good alternate energy source in the future [14]. Since agriculture is the backbone of Ethiopia's economy, and the wastes of residual after cow feed, Sorghum stalk, and Groundnut husk have almost not been successfully used yet [16].

In Ethiopia, 17 % of the populations have access to electricity. Biomass accounts for more than 90 % of Ethiopia's total energy demands. Firewood makes up 84.98 %, charcoal 3.91 %, leaves/residue 2.03%, manure/dung 5.14%, sawdust 0.07 %, butane gas/kerosene 1.43, electricity 1.32 %, and others 1.11 %. The Ethiopian Statistics Agency's 2017/18 Household Survey gave a more extensive analysis, indicating that 87.08 % of households cook with firewood and 3.91 % use charcoal. Rural homes used firewood the most, although charcoal is often used in urban areas [23]. In addition, over 80% of society lives in rural areas. As a result, family and industrial energy demand is increasing, and the current supply of fuel wood and traditional wood charcoal is insufficient to meet the demand. This necessitates replacing wood with alternative materials such as biomass briquettes made from agricultural waste. Earth Mold Kilns are the primary charcoal production technology in Ethiopia. This method has a very poor efficiency (8 to 12%) for a volume of 4 to 7 m3 wood. Charcoal manufacture is forbidden in the country. Farmers are able to make a modest amount of charcoal illegally [18,19]. However, agro wastes are not used for energy purposes; instead, they are left behind on fields and burned, deactivating minerals and causing wild animals to move. Biomass briquettes made from groundnut husk and sorghum stalks using chosen binders can be used as a low-cost energy source in rural and urban settings, reducing the need for firewood. In Ethiopia, converting agro-waste into energy is not practiced activity except in paper value. As a result, the influence of firewood on human health and environmental pollution is increasing on a daily basis. Therefore, the goals of this research are to contribute to alternative energy sources by reducing deforestation and global warming, as well as to provide sustainable energy access from selected agro wastes of sorghum stalks and groundnut husks having a better product, environmental friendliness, lower energy cost, and better combustion efficiency with less smoke.

Mass Balance Analysis

The mass balance analysis was used to assess the yield of each unit operation in the production process, beginning with drying and grinding and progressing to carbonization, grinding, sieving, mixing, briquetting, and finally drying and packaging. The easy way was to calculate the ratio between the mass in (input) and mass out (output) in each step of the processes at laboratory scale, as shown in the figure 4.24. The Process Flow for Briquettes Plant Agricultural residues of 8 kg of sorghum stalk and 5 kg of groundnut husk were dealt with during the experiment, generating approximately 2.69 and 1.26 kg, respectively, at the completion of the operations listed above. The average yield of the drying and grinding, carbonization, grinding, sieving, mixing, densification, and finally drying and packaging was 95.92%, 33.71%, 97.74%, 98.93%, 98.74%, 97.62% and 97.18% respectively.

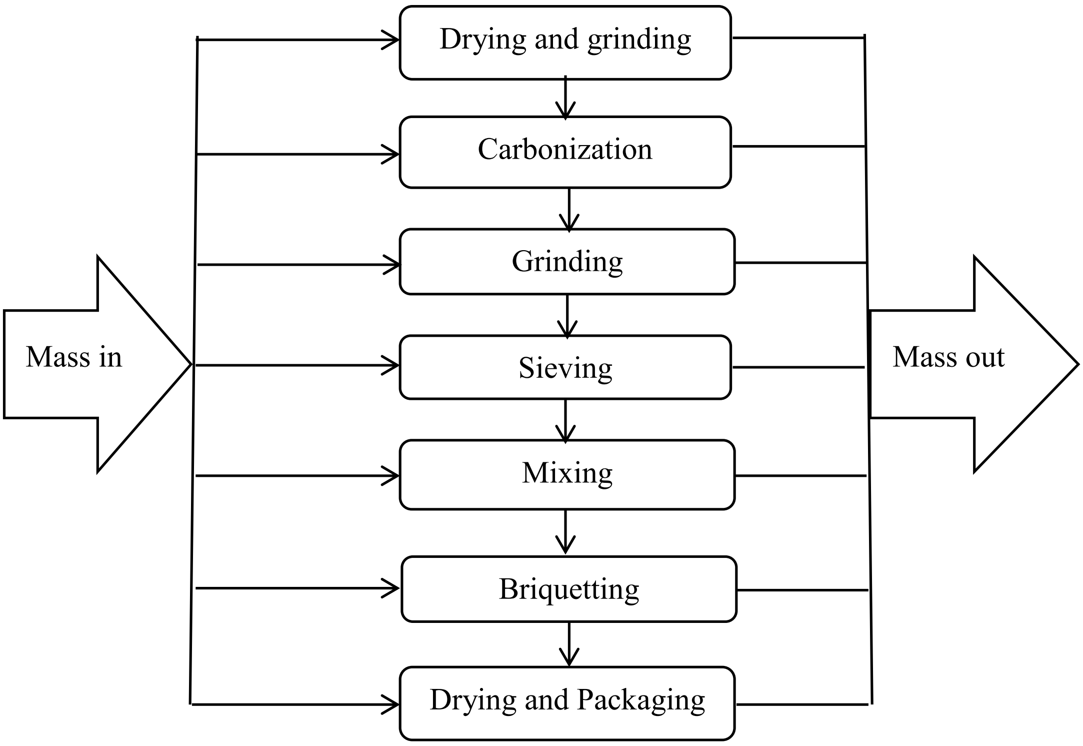

Figure 4.1: Process Flow for Briquettes Plant

The calculation part is as follow. Agricultural residues of 8 kg sorghum stalk and 5 kg groundnut husk were processed, giving approximately 2.69 and 1.26 kg, respectively, at the end of the operations. The average yield for chopping, carbonization, milling, screening, mixing, densification, and drying was 95.92%, 33.71%, 97.74%, 98.93%, 98.74%, 97.62% and 97.18% respectively. The calculation part is as follows.

Unit operation	Sorghum stalk		Groundnut husk		efficiency $= \frac{\textbf{mass out}}{\textbf{mass in}} * \textbf{100}\ \%$
	Mass In	Mass Out	Mass In	Mass Out	
Drying and grinding	8 kg	7.73	5 kg	4.76	95.92
Carbonizer	7.73	2.89	4.76	1.43	33.71
Grinding	2.89	2.84	1.43	1.39	97.74
Sieving	2.84	2.82	1.39	1.37	98.93
Mixing	2.82	2.79	1.37	1.35	98.74
Densification	2.79	2.74	1.35	1.31	97.62
Drying	2.74	2.69	1.31	1.26	97.18

Table 4.1: Efficiency of Each Process for Briquetting Plant

Economic feasibility to Production Combined Briquettes

Production of biomass briquettes requires technology, which can be high energy-powered or low energy-powered. Raw materials for the briquetting process are a major determinant of the equipment and machinery used as well as briquette's varied quality and production costs. A critical element to consider when proposing the setting up of a briquetting plant is the cost [25].

Briquetting plant cost analysis is based on the cost of biomass, machine setup, and plant location selection. The economic feasibility of each system is determined by an economic analysis of the prototype briquetting machine. Economic study of the system can be done out using the Rate of Return on Investment (ROR) and Pay-back Period as follows.

Economic Analysis of Combined Briquette

The economic feasibility of any technology including briquetting can be determined through economic analysis of same. It is also dependent on four factors, specifically the type of equipment used, the type of biomass, skills of human resource, and investment capital. The economic analysis is performed by deploying certain basic economic indicators of net present value (NPV), internal rate of return (IRR), payback period (PBP), and turnover ratio (TOR).

E/indicator	Definition	Equation
Turnover ratio	It is the ratio of gross annual sales to the fixed-capital investment and it is acceptable for a ratio between 0.2 and 5	$TOR = \frac{\text{Gross annual sales}}{\text{fixed−capital investment (FCI)}}$
Return on investment	Sum of annual profit and deprecation divided by the total initial investment represents the fractional return, and this fraction times 100% is the standard return on investment.	$ROI = \frac{\text{Net profit} + \text{Depriciation}}{\text{Total capital investemet}} * 100\%$
Payback period (PBP)	The number of years that it will take, from day one of a project, before the investment cost is fully recovered and it is acceptable when its value is less than 5 y	$PBP = \frac{\text{Depriciable FCI}}{\text{Net profit} + \text{Depreciation}}$
Break-even point (BEP) analysis	At break-even point, the total product costs are equal to the annual revenue earned. That is Total product cost (TPC) = TAS	$TPC = \text{Manfucturing cost (MC)} + \text{General expense (GE)} = \text{Total annual sales}$
Net present Value (NPV)	It treats the time value of money It is the total present worth of all cash inflow minus the total capital investment (see Appendix C)	$NPV = \sum_{t=1}^{n}(1+i)^{-n}(NP_t + D_t + Rec_t) - TCI$
Internal rate of return(IRR) or (DCFR)	Takes into account the time value of money and based on the amount of investment that is unreturned at the end of each year during the estimated life of the project. It is discount rate that makes the NPV equal to zero (See Appendix D).	$NPV = \sum_{t=1}^{n}(1+i)^{-n}(NP_t + D_t + Rec_t) - TCI = 0$

Where, i = the discount rate, n = lifetime of the plant, NP_t = net profit, D_T= depreciation, Rec_t = recovery value, and TCI = Total capital investment.

Rec_t = salvage value + working capital, Source [89]

Table 4.2: Economic Indicators for The Feasibility of Projects

Cost Assessment

Every manufacturing process requires a capital asset, and determining the necessary asset is an important aspect of a plant design project. The overall investment for each process comprises of fixed capital investment for physical apparatus and services in the plant plus working capital, which must be available to pay workers, keep raw materials and products on hand, and handle other particular items needing a direct cash outlay.

Costs for Briquette Production

The briquetting production cost, which can be denoted as the total cost, is dependent on several other costs. These other costs to include capital cost, installation cost, operation cost, repair and maintenance cost. The costs of processing equipment, briquetting machine and accessories, land, and building where necessary are basically what constitute the capital cost of a biomass briquetting system. The costs associated with mounting such equipment and machinery on site refers to the installation cost. The cost of labor, raw material, electricity, oil and lubricant for machinery, transportation, and other related inputs that enhance the smooth running of the briquetting plant essentially forms the operation cost. Finally, the repair and maintenance cost are basically comprised of expenditure made on the appropriate maintenance of the briquetting plant and machinery on a daily, weekly, monthly, or as deemed necessary basis. This involves repair or outright replacement of damaged parts, oil cleaning, and tightening of loose bolts.

Fixed-Capital Investment

The term "industrial fixed-capital investment" refers to the capital necessary for the installation of process apparatus, including all auxiliaries required for process operation. The decrease in value due to any causes during the process is a measure of depreciation.

Estimation of Capital Investment Cost (Individual Components)

The percentages representing the various costs constituting the capital investment are approximations for standard chemical processing plants. It is important to note that the values provided can vary depending on a variety of circumstances, including plant location, process type, instrumentation complexity, and so on.
• Direct costs = material and labor involved in actual installation of complete facility
(70-85% of fixed-capital investment)
• Equipment + installation + instrumentation + piping + electrical + insulation + painting
o (50 – 60 % of fixed -capital investment)
• Purchased equipment (15-40% of fixed-capital investment)
• Installation, including insulation and painting (25-55% of purchasing equipment cost)
• Instrumentation and controls, installed (6-30% of purchasing equipment cost)
• Piping, installed (10-80% of purchased-equipment cost)
• Electrical, installed (10-40 % of purchasing equipment cost)
• Buildings, process and auxiliary (10 -70% of purchasing equipment cost)
• Service facilities and yard improvements (40-100% of purchasing equipment cost)
• Land (1-2% of fixed-capital investment or 4-8% of purchased-equipment cost)
• Indict costs = expenses which are not directly involved with material and labor of actual installation of complete facility (15-30% of fixed-capital investment)
• Engineering and supervision (5-30% of direct costs)
• Construction expense and contractor's fee (6-30% of direct costs)
• Contingency (5-20% of fixed-capital investment)
• Fixed-capital investment = direct costs + indirect costs
• Working capital (10-20% of total capital investment)
• Total capital investment = fixed-capital investment + working capital

Estimation of Total Product Cost (Individual Components)

The percentages mentioned for the various costs involved in the whole operation of manufacturing facilities are approximations that apply to standard chemical processing plants. It should be noted that the values provided can change depending on a variety of circumstances, including plant location, type of procedure, and corporate policies.
Manufacturing cost = direct production costs + fixed charges + plant overhead costs
Direct production costs (about 60% of total product cost)
• Raw materials (10-50% of total product cost)
• Operating labor (10-20% of total product cost)
• Direct supervisory and clerical labor (10-25% of operating labor)
• Utilities (10-20% of total product cost)
• Maintenance and repairs (2-10% of fixed-capital investment)
• Operating supplies (10-20% of cost for maintenance and repairs, or 0.5-1% of fixed capital investment)
• Laboratory charges (10-20% of operating labor)
• Patents and royalties (0-6% of total product cost)

Fixed charges (10 -20% of total product cost)
• Depreciation (depends on life period, salvage value, and method of calculation-about 10% of fixed-capital investment for machinery and equipment and 2-3% of building value for buildings)
• Local taxes (1-4% of fixed-capital investment)
• Insurance (0.4-1% of fixed capital investment)
• Rent (8-12% of value of rented land and buildings)

Plant-overhead costs (50-70% of cost for operating labor, supervision, and maintenance, or 5 - 15% of total product cost); includes costs for the following: general plant upkeep and overhead, payroll overhead, packaging, medical services, safety and protection, restaurants, recreation, salvage, laboratories, and storage facilities.
General expenses = administrative costs + distribution and selling costs + R and D costs
• Administrative costs (about 15% of costs for operating labor, supervision, and maintenance, or 2-6% of total product

cost); includes costs for executive salaries, clerical wages, legal fees, office supplies, and communications.
• Distribution and selling costs (2-20% of total product cost); includes costs for sales offices, sales men, shipping, and advertising
• R and D costs (2-5% of every sale or about 5% of total product cost)
• Financial interest (4 -5% of total product cost)
• Total product cost = manufacturing cost + general expenses
• Gross earnings cost (gross earnings = total income - total product cost; amount of gross earnings cost depends on amount of gross earnings for entire company and income-tax regulations; a general range for gross-earnings cost is 30-40% of gross earnings) [89].

Working Capital

Industrial plants primarily use working capital, which is the entire amount of money invested in raw materials and supplies carried in stock, cash kept on hand for planned payment of operating expenses, such as salaries, wages, and raw material purchases.

Equipment	Specifications	Application/ Manufacture	Cost (birr)
briquetting machine (piston press)	✓ Capacity of briquetting machine: 1.5ton/ h ✓ Density of briquettes: 0.9 to 1.5 g/cm^3 ✓ Diameter of the briquettes: 40mm ✓ Length of the briquettes: 50 mm ✓ Motor power: 3HP ✓ Capacity utilization (> = 95%) ✓ Production capacity 4000 (kg/h) ✓ Production mode: Mechanized	Compaction/ Made in Zhengzhou Rongde Machinery Equipment Co.Ltd.	543,560
Carbonizer (kiln)	✓ Temperature range: 0-1500 ^{O}C ✓ Height 750 mm ✓ Diameter 550 mm ✓ Diameter of bottom vent 20 mm ✓ Height of bottom vent 100 mm ✓ Material Mild steel	Torre faction/ Henan Bohan Environmental Protection Technology Co.Ltd.	264,520
	✓ Efficiency 30 – 40%		
oven/ 2 pieces	✓ Make: Quality QE-102 ✓ Temperature range 50-350 ^{O}C	Proximate Analysis/ Xiamen TET	274,848
muffle furnace	✓ Make: Quality NSW-101, MF-1 ✓ Temperature range: 0 – 1200 ^{O}C ✓ Rating: 1.6 kw	Proximate Analysis/ Shanghai jingke Scientific Ins.	160,319.1
crucible with lid 0.2 $/pieces take 100 pieces	✓ Height- 38 mm ✓ External diameter- 25 mm ✓ Internal diameter- 22 mm	Holding sample for analysis	1,145.2
bomb calorimeter ASTM d240	✓ Make: Parr, Oxygen bomb	Calorific value/ Shanghai Goldsu	253,755
CHNS element Analyzer	✓ Make: Thermo Scientific-FlashEA1112 Automatic Element	Ultimate Analysis/ Shenzhen Kanghua Shengshi Co.Ltd.	104,867.1

electronic balance per piece 5.80 \$ take 2 pieces	✓ Accuracy: 0.001 g	Weight/ Dongguan Changxie	664.216
Mixer	✓ Efficiency > = 95% ✓ Excellent for high quality briquette ✓ Dual shaft	Mixing / Zhengzhou, Henan, China	463,150
grinder	✓ Efficiency > = 95% ✓ New Design Roller Grinder ✓ Reduction capacity < = 1mm	Size reduction/ Gongyi Hengchang machinery	258,753
Analytical sieve	✓ Efficiency > = 95% ✓ High RPM	Grading/ Zhengzhou, Leabon, China	195,890
water tank (3000 l)	✓ Super fiber water tank (2)	Water collection/ Ethiopia	19,000
Purchasing equipment cost (PEC)		**2,540,471.62**	

Items	**Estimation**	**Cost (birr)**
purchasing equipment cost (PEC)		2,540,471.62
electrical (installed) (10 -40)% PEC	18% PEC	457,284.89
buildings, process and auxiliary (10 -70)% PEC	40% PEC	1,016,188.65
piping installed (10 - 80) % PEC	35% PEC	889,165.07
installation, including insulation and painting (25 -55)% PEC	30% PEC	762,141.48
instrumentation and controls, installed (6 – 30)% PEC	15% PEC	381,070.74
service facilities and yard improvements (40 – 100) % PEC	60% PEC	1,524,282.97
Total direct cost (TDC)		7,570,605.42
construction expense and contractor's fee (6 -30) % dc	20% TDC	1,514,121.1
engineering and supervision (5-30)% dc	20% TDC	1,514,121.1
Total indirect cost (TIDC)		3,028,242.2
Fixed capital investment = direct cost + indirect cost		10,598,847.60
contingency (5 – 20) % FCI	10% FCI	1,059,884.76

PEC = (15 – 40) % FCI this study was taken approximately 23.97% of FCI.

Therefore, PEC = 23.97 % FCI which means $FCI = \frac{PEC}{0.2397}$

Table 4.3: Purchased-Equipment Cost for Complete Process Unit (Using Alibaba.Com)

	Estimation	**Cost/year**
DPC = Direct production costs about	60% TPC	**7,123,096.50**
Raw materials(10 -50)% TPC	30% TPC	3,255,380.67
Operating labor (OL) (10 – 20)% TPC	15% TPC	1,627,690.33
Direct supervisory and clerical labor(10 – 25)% OL	17% OL	276,707.36
Utilities(10 -20)% TPC	10% TPC	1,085,126.89
Maintenance and repairs (2 – 10)% FCI	6% FCI	635,930.86
Operating supplies(10-20)% M & R or (0.5-1)% FCI	0.75% FCI	79,491.36
Laboratory charges (10-20)% OL	10% OL	162,769.03

	Estimation	Cost/year
FC = Fixed charges (10 – 20)% TPC	15% TPC	**1,627,690.33**
Depreciation 10% of FCI for machinery equipment	10% FCI	1,059,884.76
Depreciation 2-3% of building value for buildings	2.5% Building	25,404.72
Local taxes (1 -4)% FCI	2.5% FCI	264,971.19
Insurance (0.4 -1)% FCI	0.7% FCI	74,191.93
Land rent (4 – 8)% PEC	8% PEC	203,237.73
	Estimation	**Cost/year**
POC = Plant-overhead costs (5 – 15)% TPC	10% TPC	1,085,126.89
Mc = DPC + FC + POC		9,835,913.72
General expenses = Administrative costs + Distribution & Selling costs + R and D costs		
Administration cost (2 – 6)% TPC	1.4% TPC	147,253.66
Distribution and selling cost (2 -20)% TPC	3% TPC	325,538.07
Research and development cost about 5% TPC	5% TPC	542,563.44
General expenses		1,015,355.17
Total product cost (TPC) = MC + General expenses		10,851,268.89

Table 4.4: Total Product (Operation) Cost Estimation

Cost Consideration

The annual cost of operation for briquetting machine was calculated based on the following assumption:

- The operating life of the system is 20 years.
- The briquetting machine can operate for 16 hours per day.
- Effective operating days is 300 days/yr.
- Raw material cost: The sorghum stalk and groundnut husk @ 20 birr /quintal
- Labor cost: 8 persons can be involved to produce the briquettes:
- For biomass feeding- 2 scholar with labor charges @ 5000 birr for each and
- For briquette collection – 3 with labor charges @ 2500 birr for each were considered.
- For grinder, drying and packging-3 with labor charges @ 2500 Birr/month for each person.
- Electricity cost: The cost of electricity for one unit is considered @ 0.54 birr/kWh (Unit)
- Exchange rate: 135.3995 ETB = 1 USD $ (September, 2024)
- Electricity cost: 2.85 birr/ kwh

Working capital	Cost (birr/yr.)
✚ Raw material cost for SS and GH assumes equal cost per quintal:	2,880,000
✓ 1 quintal raw material = 15 birr from the field	
✓ The capacity of the machine is 4000 kg/hour for piston press	
Total raw material cost per year $= 15\ \frac{\text{birr}}{\text{quintal}} * 0.01\ \frac{\text{quintal}}{\text{kg}} * 4000\ \frac{\text{kg}}{\text{hr.}} * 16\ \frac{\text{hrs}}{\text{day}} * 300\ \frac{\text{days}}{\text{yr.}}$	
✚ Labor cost for 8 operating people	2,400,000
✓ For biomass feeding- 2 scholar with labor charges @ 5000 birr for each	
✓ For biomass collection- 3 with labor charges @ 2500 birr for each	
✓ For grinder, drying and packging-3 with labor charges @ 2500 birr/month for each person. Then total labor cost= 25000 birr/month*8 person*12 month/year	

Electricity charges, @ 0.6943 birr/kwh: $= 2.85 \frac{\text{birr}}{\text{kwh}} 3\text{ hp} * 0.745 \frac{\text{kwh}}{\text{hp}} * 20 \frac{\text{hr}}{\text{day}} * 300\text{ day}$	9,310.56
Water charges, @ 5.5 birr/m^3 = 6000 $\frac{m^3}{yr} * 5.5 \frac{birr}{m^3}$	33,000
Working capital cost (WCC)	5,322,310.56
Total capital investment = Fixed capital investment + WCC	15,921,158.16

Table 4.5: Working Capital Cost (Birr/Year)

Total manpower requirement includes skilled and unskilled labor. Similarly, the total Annual labor cost including fringe benefits, is projected to be Birr 2,400,000 as shown in the above table. Since fixed charges occupied (10 -20) % of total product cost, so using the average fixed charges around 15 % the total product cost was calculated and finally obtained 10,851,268.89 birr/year.

Feasibility Analysis

Assumptions

The cost of the produced fuel briquette with unit selling price distributed to users is at 5 Birr /kg and Tax rate = 35% with interest rate = 12%, the plant works at its complete capacity, Minimum acceptable return (MAR) for new process technology the MAR is between 16-24% [89], briquette consumed by users 850 kg/hr and constant net profit in each year.

$$\text{Total annual briquette produced} = 850 \frac{\text{kg}}{\text{hr}} * 16 \frac{\text{hr}}{\text{day}} * 300 \frac{\text{day}}{\text{year}} = 4{,}080{,}000 \frac{\text{kg}}{\text{year}}$$

$$\text{Total annual briquette sale} = \text{Selling price} * \text{Total annual briquette produced}$$

$$= 5 \frac{\text{Birr}}{\text{kg}} * 4{,}080{,}000 \frac{\text{kg}}{\text{year}} = 20{,}400{,}000 \frac{\text{birr}}{\text{year}}$$

$$\text{Direct production cost of briquette per unit} = \frac{\text{total direct production cost}}{\text{total annual briquette produced}}$$

$$= \frac{7{,}123{,}096.50\text{ bir}}{4{,}080{,}000\ \ kg} = 1.75 \frac{\text{birr}}{\text{kg}}$$

- $\text{Gross income} = \text{Total annual sales} - \text{total capital investement}$

$$= 20{,}400{,}000 \frac{\text{birr}}{\text{year}} - 15{,}921{,}158.16 \frac{\text{birr}}{\text{year}} = 4{,}478{,}841.84 \frac{\text{birr}}{\text{year}}$$

- $\text{Net Profit (NP)} = \text{Gross income} - \text{Taxes}$

$$\text{NP} = \text{Gross income} * (1 - \text{Tax rate}) = 4{,}478{,}841.84 * 0.65 = 2{,}911{,}247.20 \frac{\text{birr}}{\text{year}}$$

The return on investment (ROI), the payback period, and the turnover ratio, was calculated using the formula in the above table. Then,

- $\text{MAR} = \frac{\text{Net profit}}{\text{Total capital investment}} * 100\ \% = 18.29\ \%$; For new product earning into established market or new process technology minimum acceptable return (MAR) is between 16-24% [89] so it is Acceptable.

- $\text{Turnover ratio (TOR)} = \frac{\text{Gross annual sale}}{\text{fixed-capital investment (FCI)}} = \frac{20{,}400{,}000}{10{,}598{,}847.60} = 1.93$

  It is acceptable because the ratio is suitable in between 0.2 and 5

- $\%\text{ROI} = \frac{\text{Net profit} + \text{Depriciation}}{\text{Total capital investemet}} * 100 = \frac{2{,}911{,}247.20 + 1{,}085{,}289.48}{15{,}921{,}158.16} * 100\% =$ 25.10% ; If % ROI ≥ MAR, the project is feasible otherwise reject it.

Therefore, the project is visible since it is greater than minimum acceptable return (MAR)

- $PBP = \frac{\text{depreciable FCI}}{\text{Net profit+Depreciation}} = \frac{10{,}598{,}847.60}{2{,}911{,}247.20 + 1{,}085{,}289.48} = 2.67 \sim 3 \text{ year}$

The project initial investment will be fully recovered within 3 year. Therefore, the project is visible since pay-back period less than 5 years is advised in chemical engineering prospective.

- Using the above table break-Even Point (BEP) Analysis can be estimated as following:

The point @ TPC = TAS

Where, $TPC = \text{Manufacturing cost } (MC) + \text{General expense } (GE) = \text{Total annual sales}$

Manufacturing cost + General expenses = 9,835,913.72 birr/year + 1,015,355.17 birr/year

= 10,851,268.89 birr/year; Or can solve using this formula: S x n =DPC x n + TPC

Where, n =break even quantity or capacity, TPC= total product cost, DPC= direct production cost per unit, S= selling price per unit

Therefore, $10{,}851{,}268.89 \frac{\text{birr}}{\text{year}} + n * 1.75 \frac{\text{birr}}{\text{kg}} = n * 5 \frac{\text{birr}}{kg}$ rearrange and solve for n,

$$n = \frac{10{,}851{,}268.89}{3.25} = 3{,}338{,}851.97 \frac{kg}{year}$$

If break even capacity < Assumed capacity, the project is feasible, so the project is feasible

- $\% \text{ Break even analysis} = \frac{\text{Production capacity at BEP}}{\text{Annual briquette production +Annual Depriciation}} * 100\ \%$

$$= \frac{3{,}338{,}851.97}{4{,}080{,}000 + 1{,}085{,}289.48} * 100\ \% = 64.64\%$$

As the rule of thumb for viable project, percentage of break-even capacity should be between (60-65) percent. Therefore, this project is feasible because it is in the range.

According to Kpalo, Sunday Yusuf Zainuddin, Mohamad Faiz Net Present Value is used to determine the profitability of a project with an average 20 years economic life [25]. A positive NPV means the project can be accepted, but should be rejected when negative, and can make the investor indifferent when it is zero.

- $NPV = \sum_{t=1}^{20} (1+i)^{-n} (NP_t + D_t + Rec_t) - TCI$; Annual cash flow = NP + D + Rec_t

$$= 2{,}911{,}247.20 \frac{\text{birr}}{\text{year}} + 1{,}085{,}289.48 \frac{\text{birr}}{\text{year}} + 5{,}322{,}310.56 \frac{\text{birr}}{\text{year}} = 9{,}318{,}847.24 \frac{\text{birr}}{\text{year}}$$

If the NPV is greater than 0, the project is economically acceptable as it will bring profit to the investor. Then the net benefit value increases and got positive sign at the 20 years of the project lifetime. It increases and the research found will get cumulative of more than 51,245,304.44 birr after 20 years. So, this briquetting project is profitable and feasible since NPV is positive.

- Internal rate of return (IRR) or (DCFR) can obtain by try and error at NPV = 0.

The discount cash flow rate of return was estimated using equation bellow at the briquette plant life of 20 years as shown in the above table using an excel solver to estimate the discount rate.

$NPV = \sum_{t=1}^{20} (1+i)^{-n} (NP_t + D_t + Rec_t) - TCI = 0$, using excel solver IRR becomes 16.87456%

Methods of Profitability Analysis	Results	Kpalo, Yusuf Zainuddin, Mohamad Faiz [79]		
		Cashew shell	Grass	Rice husk
Minimum acceptable return, %	18.29	Nd	N,d	N,d
Turnover ratio	1.93	2.8	2.93	1.51
Return on investment, %	25.10	N,d	N,d	N,d
Payback period, Year	2.67 ~ 3	0.68	0.63	2.5

Break-Even Point, %	64.64	N,d	N,d	N,d
Net Present Value, ETB	51,245,304.4	$25,831.88	$30,117.20	$1.40 million
Internal rate of return, %	16.87456	36	68	76

N, d is to mean not determined

Table 4.6: Result Summary for Profitability Analysis

Effect of Briquette on Environment and Socio-Economic Aspect

For household cooking, Biomass accounts for more than 90% of Ethiopia's total energy demands, Firewood makes up 84.98%, 1.43% gas/kerosene/oil, 3.91% use charcoal, 2.03% use agricultural residues, and others. The majority of the energy is derived from fuel wood (wood, charcoal, and wood residues), which contributes to environmental issues such as deforestation. Using briquettes as a substitute for fuel wood allows the limitation of GHGs, especially CO_2 and CH4. Briquette is more cost-effective and Eco-friendlier than other fuels since it is a carbon-neutral form of energy. The carbon released during burning can be consumed by the trees. Some studies on briquettes have shown that they release a very little amount of Sulphur and nitrogen during burning. Briquette production will help to preserve air quality. In addition, the activities of densification of these agro residues would contribute to environmental sanitation. Finally, the use of briquettes will prevent the deterioration of forests. Biomass briquettes could be formed at a local level. This provides an advantage to local societies and farmers by allowing them to develop creativity on business and economically profitable. Poverty and rural-to-urban migration might also be reduced in rural areas. Definitely, in rural areas will also create jobs.

Sustainable energy source that lower pollution, deforestation, waste management, and CO_2 emissions, all of which have an impact on the environment. In terms of socioeconomic benefits, this alternative energy will boost local economies, create jobs, reduce energy costs, improve energy efficiency, and raise producer income. Therefore, this alternative energy offers a more affordable and efficient fuel source than conventional options like wood charcoal or fossil fuels, briquettes generally have a positive socioeconomic and environmental impact. However, challenges and considerations such as lack of technology, need for skilled labor, government support, production logistics, possible labor problems during production, health and safety in production, and the requirement for professional garbage sorting can prevent them from being widely used and having their full impact.

Conclusion and Recommendation

Conclusion

Today the world is suffering in rising population growth and this also derives with increasing energy demand. Records have shown that there is a lot of pressure on fossil fuel, which is decreasing at a fast rate and whose growing utilization has consequential effects leading to climate change. To predict future energy crisis and climate change, it has become vital to source for alternative energy supply. Biomass presents an opportunity to reduce dependence on fossil fuels. The challenge with biomass is that it is usually low in bulk and energy density, which poses a problem of handling, transportation, and storage. This problem is however controlled by briquetting, which also improves the biomass density, burn time, and the calorific value. This paper reviewed studies on development of briquette suitable for energy generation from residue of cattle feed sorghum stalk and groundnut husk. Since agricultural residues of sorghum stalk and Groundnut husk were among the most available in Ethiopia. This study examined physical and combustion properties of sorghum stalk, Groundnut husk and composite briquettes like density, shatter Index, proximate and ultimate analysis, calorific values and optimization of the study. The effects of particle size, binder composition and ratio on the briquette's qualities were studied. The data were investigated and optimized using ANOVA, DOE and Microsoft Excel.

Based on the results, it has been found that higher values were obtained with 1 mm particle size and 25% CD binder respectively as follows, for combined briquette higher VM 80.20%, higher density 1.202 g/cm3, higher CV 24.36 MJ/kg, higher shatter Index 96.19% and low AC 3.6% and low MC 3.16%. Therefore, Density and shatter Index were increased as particle size decreased and increasing binder composition using cow dung binder. A higher density indicates higher energy per unit volume and high shatter Index signifies higher strength important for transport and storage. Combined briquette had 51.56% C, 6.302% H2, 0.0042% N2, and 42.134% O_2 contents and 0.00093% sulfur content was obtained. So, the briquettes are spotless environmentally friendly due to their low pollutants. Additionally, successful briquetting requires financing and it is necessary to evaluate its economic viability since the products are meant to serve as alternatives to existing fuels. This evaluation is achieved by analyzing the various costs involved including economic indicators such as NPV, PBP, IRR, MAR, ROI, BEP and TOR with 51,245,304.44-birr, 2.67 year, 58.4689%, 18.29% 25.10% 64.64% and 1.93 respectively for this study. The produced briquettes will be used in both rural and urban areas for domestic heating applications due to the calorific value gained were above 13 MJ/kg. They can also be utilized in industrial applications for heating and energy productions such as gasification due to its calorific value gained were above 17 MJ/kg [27-32].

Recommendations

Based on the study made on briquette of sorghum stalk and Groundnut husk the following recommendations were given.

• Effective design of Carbonizer will enhance much better the energy density yield of biomass. So, by designing actual Carbonizer with a better heat source (Automatic controller heat source) should be recommended for better temperature control, to heat distribution equally throughout the sample and more biomass can be carbonized.
• Researches should be done on other environment-friendly binders and observe their effects on the performance of briquette can be studied. Some of the possible binders may be molasses, wastepaper, starch and others.
• Low pressure compaction bellow 5 MPa with cow dung bending agent was used in this study. So, using the effect of high and medium pressure compaction and temperature will be essential to reflected in other studies. Because they are significant towards improving the quality of fuel briquettes produced at high and medium pressures and temperature to densifying. This means that appropriate briquetting machine capable of producing such quality briquettes at low costs suitable for local communities needs to be developed.

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Appendix

Appendix A: Experimental Instruments, Raw Material and Samples of Briquettes


8. Grinding the Char
9. Sieving/ Grading
10. CD binder
11. Mixing
12. Manual press briquetting machine

Appendix-B1: Proximate Analysis and Calorific Value Assessment

A) Raw material form