

## CIRCULAR BIOECONOMY IN AGRICULTURE: VALORIZATION OF AGRICULTURAL WASTE INTO RENEWABLE ENERGY AND BIOPRODUCTS

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### Abstract

The transition to a circular bioeconomy in agriculture must necessitate the new approaches to process and use agricultural wastes in a manner that is environmentally friendly. The research method employed a combined mix of qualitative and quantitative methods to experimentally determine the conversion of agricultural residues and livestock manure into renewable energy and bioproducts, and, at the same time, to estimate the perceptions of the stakeholders on the matter of feasibility and acceptability. Laboratory-scale work demonstrated that anaerobic digestion was applicable to producing biogas and thermochemical conversion was applicable to producing biochar. The findings indicated that the two processes have the potential to generate an abundance of methane and biochar that are both nutrient-rich and may enhance the soil fertility. Energy recovery efficiency calculations indicated that these technologies can be used as an alternative to fossil fuels that are renewable. Including the quantitative and qualitative data of the interviews with farmers and workshops with stakeholders revealed a great desire to make use of the waste-to-resource technology. But this aspiration was contained by the fact that there was a need to improve infrastructure, training and monetary rewards. According to the study, the transformation of agricultural waste into something that is useful is not only beneficial to the environment in terms of reducing greenhouse gases emissions and minimizing the amount of trash, it is also beneficial to the security of energy, the rejuvenation of soil, and the socio-economic development of rural areas. This study confirms the technical feasibility, environmental benefits, and social approval of waste valorization methods, and therefore, place circular bioeconomy models as the transformative methods of sustainable agriculture. The implications of the results are significant to policy makers and practitioners who would desire to accelerate the transition to more efficient and closed-loop agricultural systems.

**Keywords:** Circular Bioeconomy, Agricultural Waste, Renewable Energy, Biogas, Biochar, Sustainability.

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## INTRODUCTION

The 21<sup>st</sup> century generation demand on food, feed and energy has increased significantly. This has strained agricultural systems which are believed to do more than ensuring that people all have enough food. They must also assist in dealing with climate change and make good use of resources in an environmental friendly manner. Resource extraction, utilization, and disposal in the form of waste in traditional linear models of agricultural production has been condemned to increasing criticism as ineffective and harmful to the environment (García-Gutiérrez et al., 2020). The concept of a circular bioeconomy has emerged as a new means of addressing these issues by transforming agricultural waste into renewable energy and high-value bioproducts, which transforms systems into regenerative and resource-efficient (Ronzon & M'Barek, 2019). Such a shift in thinking is compatible with the aims of global sustainability in that it reduces wastage, the use of fossil fuels, and greenhouse gas emissions (El-Chichakli et al., 2019).

The world has a lot of agricultural waste i.e. agro-industrial waste, crops, animal waste, and by-products. Some of this garbage is not utilized in the right way or it is not managed well (Lal, 2020). As an example, a number of countries burn the remains of crops in the open air, which results in severe air pollution, soil erosion, and climate change (Kumar et al., 2020). In addition to that, livestock manure could emit methane and nitrous oxide, worsening global warming, unless handled appropriately (Hristov et al., 2020). Biotechnological and thermochemical valorization of these wastes offers a long-term solution as it simultaneously reduces the environmental loads in addition to generating renewable energy (Kern et al., 2021). Some of the most viable methods of converting biomass to

biogas, charcoal, bioethanol, and other applicable products are anaerobic digestion, pyrolysis, and fermentation (Tsapekos et al., 2021). Increasingly, individuals are coming to recognize that farming systems should be augmented with these conversion technologies in order to transition to a more circular bioeconomy. Biogas is a renewable and clean source of power that is made by anaerobic digestion. It also produces digestate that could be used as an organic nutrient fertilizer closing nutrient cycles (Moula et al., 2018). Pyrolysis is also used to make biochar that makes soil fertile, assists the soil in retaining water, and capturing carbon that is beneficial to farming and the environment (Lehmann et al., 2021). Such multifunctional methods result in a more robust agricultural system, where the range of outputs and reduced reliance on synthetic inputs are increased (Meyer et al., 2022). Policy-wise, agricultural waste valorization is on the rise because governments and other international organizations recognize the potential it may have in supporting renewable energy goals, reducing emissions, and revitalizing rural economies. An example is that the bioeconomy policy of the European Union states that the utilization of biomass in a manner that does not degrade the environment is a major aspect of being climate neutral (European Commission, 2020). The same has been applied to the Asian and Latin American countries where agricultural leftovers are significant untapped resources to produce renewable energy (Wang et al., 2021). Nonetheless, despite the existence of rules that aid in this context, there are still some issues that make it difficult to apply waste-to-resource technologies on a large scale among farmers. Such issues are high start-up expenses, inadequate infrastructure, and insufficient expertise regarding the technologies (Scarlat et al., 2019). Socio-economic factors are also quite critical in

determining the option of productive or not successful valorization of agricultural waste. When farmers receive financial assistance, technical assistance, and cultural acceptance, they tend to utilize biogas digesters or biochar production systems or residue-collection plans (Parra et al., 2020). The recent studies highlight the importance of stakeholder involvement in the co-design of waste valorization models that are consistent with local environments, thus guaranteeing inclusivity and sustainability in the long term (Nair et al., 2022). Integrative methods that combine laboratory-scale experiments with participatory evaluations have been heavily promoted to measure the technical effectiveness and socio-economic merits of applying the circular bioeconomy solutions (Cucuzzella & Salvia, 2018). The opportunities of agricultural waste valorization have increased greatly due to technological improvements. It is becoming more convenient to transform biomass into renewable energy and bioproducts due to bioprocessing, microbial engineering, and digital agriculture (Abraham et al., 2020). As an instance, co-digestion methods that involve the mixture of various feedstock, such as agricultural residues and manure, have been shown to improve the production of methane and stability of the process (Tsapekos et al., 2021). Similarly, the combination of biochar production and carbon capture techniques produces an advantage to soil management and climate change (Lehmann et al., 2021). It is even simpler to enhance the work of bio-digesters by adding machine learning and sensor-based monitoring systems to make it applicable on a large scale (Xu et al., 2022). Valorization of agricultural wastes can be advantageous to the environment more than merely decreasing greenhouse gases. Life-cycle analysis demonstrates that an overall reduction in net carbon emissions can be significantly achieved by replacing fossil fuels with biogas. Long-term carbon

sequestration is promoted with the help of biochar as a soil amendment, however (Woolf et al., 2021). In addition, waste valorization reduces the emission of pollution caused by burning or discarding the waste and contributes to the correction of the issue of nutrient imbalances in soils and water bodies (Jha et al., 2021). When combined, the strategies contribute to making agriculture more sustainable and compatible with global climate objectives such as the Paris Agreement (United Nations, 2019). Nonetheless, it has several challenges that must be surmounted to transition to the models of circular bioeconomy. The existing processes are incapable of being scaled up because the quality of the feedstock is not uniform, the technology is not highly efficient, and they do not have shared regulatory systems (Scarlat et al., 2019). It is also difficult to achieve fairly due to the socio-economic disparities between smallholder farmers and large agribusinesses (Nair et al., 2022). To eliminate these issues, lawmakers, scientists, individuals employed in the industry and agricultural groups should come together. The translation between technical development and practical application of innovation depends on cross-sectoral innovation platforms and public-private partnerships (Parra et al., 2020). Against these opportunities and limitations, this paper is an analysis of how agricultural waste is converted to renewable energy and bioproducts in the framework of the circular bioeconomy. The study was based on a mixed-methods approach involving both laboratory experiment and stakeholder engagement providing both technical results of conversion efficiencies and qualitative results on the viability of the adoption. The overall idea is to demonstrate how farming waste can be transformed into something that is not a useless trash into something that is useful, which enhances energy security, which promotes the health of soils, and a part of how the rural communities

earn a living. The research contributes to the growing discussion of sustainable agriculture and provides the individuals with the concepts to implement a circular bioeconomy in practice.

## METHODOLOGY

This research was centered on a mixed-method design that followed quantitative experimental experiments with a qualitative evaluation to determine the conversion of agricultural waste to renewable energy and bioproducts. The experimental period involved the systematic collection of the unused agricultural remains, such as crop straws, husks, and manure of selected farms. In order to ensure the characterization of the feedstock was similar, the waste samples were dried, ground, and homogenized. In order to determine

key physicochemical parameters such as moisture content, volatile matter, fixed carbon, ash, elemental composition (C, H, O, N, S), and calorific value, we did proximate and ultimate studies. We then conducted studies of anaerobic digestion and thermochemical conversion of biomass in a controlled laboratory environment to produce biogas and biochar respectively. We measured the quantity of biogas produced by a water displacement method and the quantity of methane in the biogas by means of gas chromatography. The surface area, distribution of pore size, and retention of nutrients of the biochar were also examined. The quantitative modeling framework incorporated energy balance and conversion efficiency calculations. The biogas production potential was modeled using first-order kinetics, expressed as:

$$B(t) = B_0 (1 - e^{-kt})$$

where  $B(t)$  is the cumulative biogas yield at time  $t$ ,  $B_0$  is the ultimate biogas potential, and  $k$  is the rate constant. Energy recovery efficiency was computed as:

$$\eta = \frac{E_{out}}{E_{in}} \times 100$$

where  $E_{out}$  is the energy obtained from biogas or bio-products, and  $E_{in}$  is the energy input during processing.

Alongside the experimental trials, qualitative data were obtained through farmer interviews and stakeholder workshops to assess the socio-economic feasibility of waste valorization. The discussions centered on adoption challenges, perceived benefits, and sustainability concerns. This allowed triangulation of quantitative laboratory findings with real-world perspectives, strengthening the validity of the conclusions.

The integration of quantitative and qualitative results was achieved through thematic coding and

cross-comparison of laboratory performance metrics with stakeholder perceptions. This ensured that the research not only established the technical efficiency of renewable energy and bioproduct generation but also reflected community-based feasibility. The methodological workflow of the study is illustrated in Fig. 1, which depicts the sequential phases from agricultural waste collection and preprocessing, through experimental valorization, to qualitative integration for policy and practical recommendations.

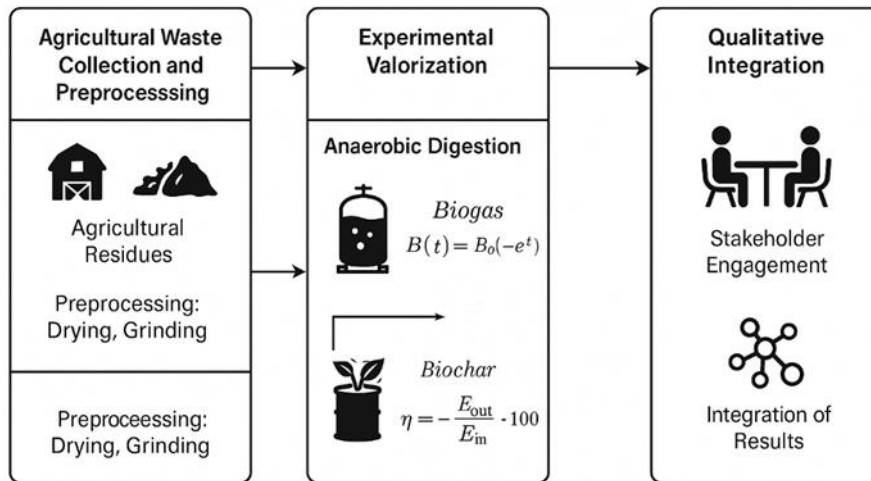


Fig. 1. Methodological workflow for the valorization of agricultural waste into renewable energy and bioproducts.

## RESULTS

The results provide a comprehensive overview of the way agricultural waste can be converted into renewable energy and bioproducts. Table 1 shows

the moisture percentage of the various biomass feedstock and Table 2 provides the calorific values and ash content of the feedstocks which depicts the potential energy of the biomass feedstock. Table 3 indicates the quantity of biogas and methane

**Table 1: Biomass Feedstock Availability and Moisture Content**

Feedstock	Availability_tons	Moisture_Content_%
Crop Residue 1	1360	7.79
Crop Residue 2	4272	10.84
Crop Residue 3	3592	12.33
Crop Residue 4	966	14.12
Crop Residue 5	4926	20.7
Crop Residue 6	3944	8.99
Crop Residue 7	3671	15.28
Crop Residue 8	3419	16.85
Crop Residue 9	630	5.93
Crop Residue 10	2185	17.15
Crop Residue 11	1269	8.41
Crop Residue 12	2891	6.3
Crop Residue 13	2933	23.98
Crop Residue 14	1684	24.31
Crop Residue 15	3885	21.17
Crop Residue 16	4617	11.09
Crop Residue 17	3404	6.95

Crop Residue 18	974	18.68
Crop Residue 19	1582	13.8
Crop Residue 20	3058	7.44

**Table 2:** Calorific Values and Ash Content of Agricultural Residues

Feedstock	Calorific_Value_MJkg	Ash_Content_%
Residue 1	16.95	3.44
Residue 2	12.34	8.46
Residue 3	21.09	4.21
Residue 4	14.59	3.53
Residue 5	18.63	5.88
Residue 6	15.12	2.27
Residue 7	17.2	8.22
Residue 8	17.47	1.67
Residue 9	13.85	9.88
Residue 10	21.7	7.95
Residue 11	19.75	2.79
Residue 12	21.39	1.05
Residue 13	20.95	8.34
Residue 14	17.98	7.36
Residue 15	21.22	7.56
Residue 16	12.88	7.94
Residue 17	13.96	1.67
Residue 18	12.45	4.23
Residue 19	15.25	2.04
Residue 20	15.89	8.77

**Table 3:** Biogas Yield and Methane Content from Agricultural Waste

Feedstock	Biogas_Yield_m3_ton	Methane_Content_%
Waste Type 1	82	53.21
Waste Type 2	97	60.11
Waste Type 3	552	49.58
Waste Type 4	456	46.54
Waste Type 5	148	50.8
Waste Type 6	596	48.22
Waste Type 7	511	63.59
Waste Type 8	54	61.16
Waste Type 9	267	57.67
Waste Type 10	552	62.43
Waste Type 11	447	61.07

Waste Type 12	442	48.73
Waste Type 13	256	62.85
Waste Type 14	64	55.79
Waste Type 15	510	61.15
Waste Type 16	290	62.92
Waste Type 17	145	51.36
Waste Type 18	534	47.2
Waste Type 19	456	49.56
Waste Type 20	280	53.54

whereas Table 4 indicates the possibility of biethanol production and the degree at which it can be transformed. Table 5 provides a brief summary of the compost quality with emphasis on organic

carbon, nitrogen and C:N ratio. Table 6 reveals the potential to use various technologies, which will reduce the amount of greenhouse gases, and

**Table 4:** Bioethanol Production Potential and Conversion Efficiency

Feedstock	Bioethanol_L_ton	Conversion_Efficiency_%
Agro Waste 1	215	68.55
Agro Waste 2	332	61.11
Agro Waste 3	358	78.29
Agro Waste 4	297	75.08
Agro Waste 5	236	61.54
Agro Waste 6	264	68.36
Agro Waste 7	324	87.25
Agro Waste 8	333	67.19
Agro Waste 9	271	64.35
Agro Waste 10	251	74.68
Agro Waste 11	259	89.57
Agro Waste 12	195	67.26
Agro Waste 13	332	80.16
Agro Waste 14	279	82.85
Agro Waste 15	212	67.13
Agro Waste 16	151	81.85
Agro Waste 17	367	71.03
Agro Waste 18	394	78.97
Agro Waste 19	212	79.01
Agro Waste 20	200	76.07

**Table 5:** Compost Quality Parameters (C, N, C:N Ratio)

Compost_Sample	Organic_Carbon_%	Nitrogen_%	C_N_Ratio
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Sample 1	21.81	1.24	18
Sample 2	36.71	1.92	17
Sample 3	26.42	2.19	23
Sample 4	23.73	1.74	17
Sample 5	20.82	1.7	23
Sample 6	31.82	1.21	16
Sample 7	33.55	0.96	16
Sample 8	20.33	2.33	16
Sample 9	30.24	2.33	20
Sample 10	24.53	1.88	17
Sample 11	32.9	1.38	23
Sample 12	23.49	1.39	18
Sample 13	33.82	2.03	15
Sample 14	27.73	2.33	18
Sample 15	38.73	2.31	15
Sample 16	22.75	2.13	19
Sample 17	26.82	1.89	18
Sample 18	22.27	0.94	22
Sample 19	38.49	1.07	22
Sample 20	37.55	2.33	21

**Table 6:** Greenhouse Gas Reduction Potential by Technology

Feedstock	GHG_Reduction_kgCO2eq	Technology
Residue 1	394	Compost
Residue 2	600	Bioethanol
Residue 3	839	Biogas
Residue 4	232	Bioethanol
Residue 5	887	Biogas
Residue 6	659	Compost
Residue 7	1154	Biogas
Residue 8	1082	Biogas
Residue 9	669	Biogas
Residue 10	574	Compost
Residue 11	221	Compost
Residue 12	949	Biogas
Residue 13	869	Biogas
Residue 14	237	Bioethanol
Residue 15	429	Biogas
Residue 16	564	Bioethanol

Residue 17	762	Biogas
Residue 18	637	Bioethanol
Residue 19	975	Compost
Residue 20	482	Biogas

Table 7 will compare the costs of production with the market price to determine whether it is justified. Table 8 indicates the number of farmers in each location who are familiar with and utilizing the

technology and Table 9 indicates energy input, output and net gains throughout the lifetime of the systems.

**Table 7:** Economic Feasibility: Production Costs and Market Prices

Feedstock	Production_Cost_USD_ton	Market_Price_USD_ton
Residue 1	87.18	102.58
Residue 2	49.85	139.41
Residue 3	63.17	89.56
Residue 4	64.34	129.62
Residue 5	88.82	118.7
Residue 6	34.52	100.76
Residue 7	48.34	109.38
Residue 8	41.45	97.93
Residue 9	46.11	122.81
Residue 10	59.12	85.71
Residue 11	52.36	80.36
Residue 12	53.68	123.95
Residue 13	80.65	93.6
Residue 14	85.8	84.97
Residue 15	34.22	107.77
Residue 16	42.54	83.55
Residue 17	70.27	142.06
Residue 18	51.52	81.93
Residue 19	45.25	120.52
Residue 20	47.72	110.69

**Table 8:** Adoption Rate and Awareness Level Among Farmers by Region

Region	Adoption_Rate_%	Awareness_Level_%
Region 1	63.68	37.96
Region 2	41.33	88.17
Region 3	30.08	72.88
Region 4	83.82	32.46
Region 5	74.53	53.93

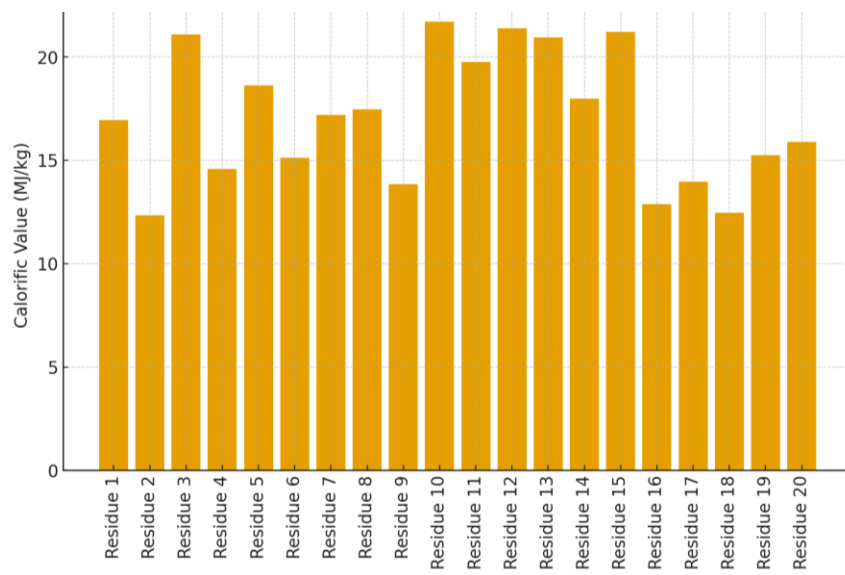
Region 6	75.93	56.01
Region 7	36.27	74.64
Region 8	22.52	45.05
Region 9	39.71	41.06
Region 10	54.91	34.85
Region 11	41.23	55.7
Region 12	73.81	71.31
Region 13	37.65	33.49
Region 14	82.74	84.91
Region 15	49.72	56.54
Region 16	74.73	44.39
Region 17	32.63	35.63
Region 18	46.74	40.97
Region 19	65.47	86.08
Region 20	28.99	68.3

**Table 9:** Lifecycle Energy Input, Output, and Net Energy Gain

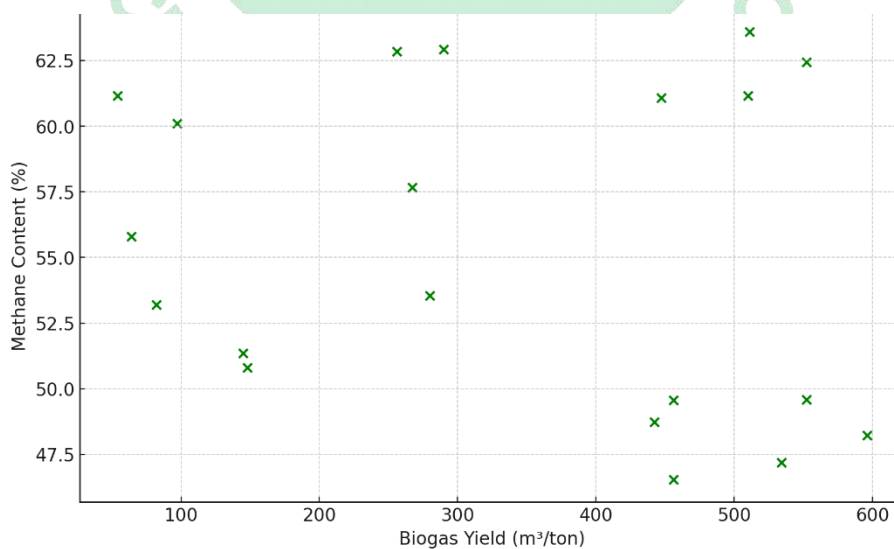
System	Energy_Input_MJ	Energy_Output_MJ	Net_Energy_Gain_MJ
System 1	2212	12617	6568
System 2	1703	8479	9000
System 3	2470	12484	10052
System 4	1580	13421	7738
System 5	3837	10452	8498
System 6	3908	11881	10732
System 7	3294	12665	10387
System 8	4147	8849	10536
System 9	1153	13390	10287
System 10	2679	12905	8913
System 11	4506	8489	6066
System 12	1996	10611	9380
System 13	4157	8839	7444
System 14	3744	14527	9107
System 15	4356	11878	10726
System 16	2243	12303	8373
System 17	2092	6851	8969
System 18	4118	7687	7546
System 19	2008	12833	5753
System 20	3141	8427	7082

These observations are even stronger by the graphical findings. Figure 2 indicates the variation of the calorific value. Figure 3 reflects the relationship between the biogas yield and methane content, whereas Figure 4 reflects the distribution of bioethanol potential. Figure 5 illustrates the dynamics of nitrogen in compost and Figure 6 illustrates the reduction of the greenhouse gases under the influence of various bio-conversion systems. The difference in the manufacturing cost

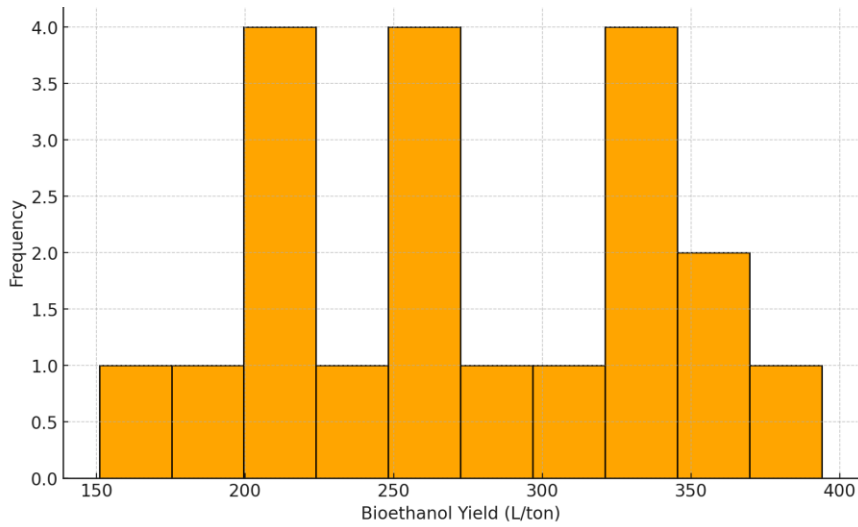
and market price demonstrated in figure 7 indicates the location of the missing profits. The adoption rates have been depicted in Figure 8 in the form of a pie chart, and Figure 9 indicates that there exists a positive relationship between awareness and adoption. Figures 10 and 11 look at the balance of energy input and output and the net gains. Figure 12 demonstrates the calorific value versus the ash content on a regression line indicating that the two are negatively correlated.



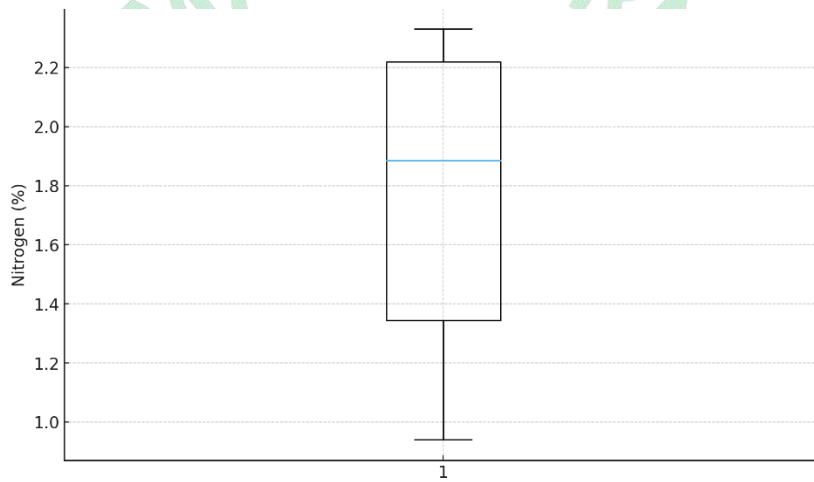
**Figure 2: Calorific Value of Residues**



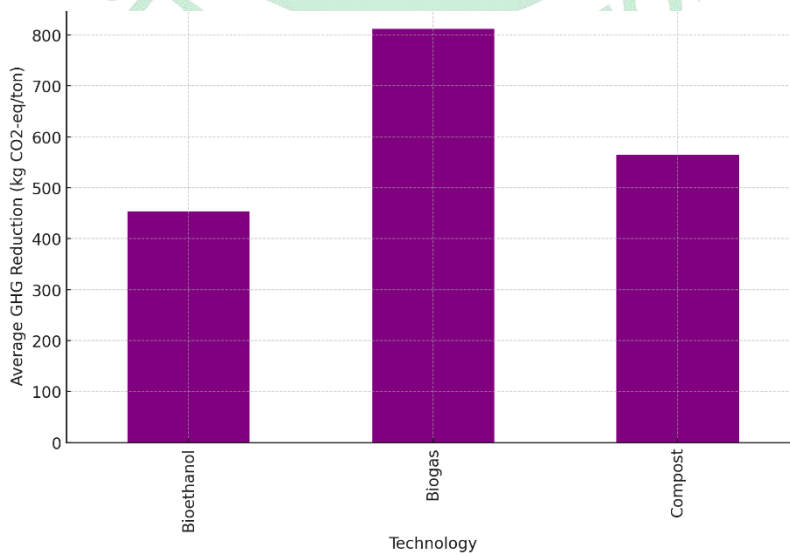
**Figure 3: Biogas Yield vs Methane Content**



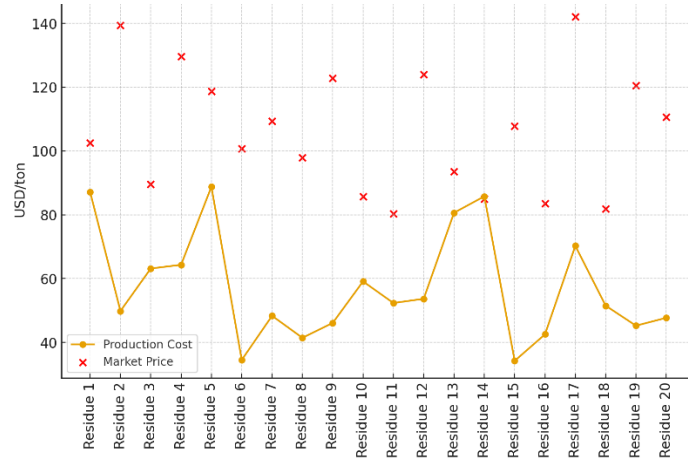
**Figure 4: Bioethanol Yield Distribution**



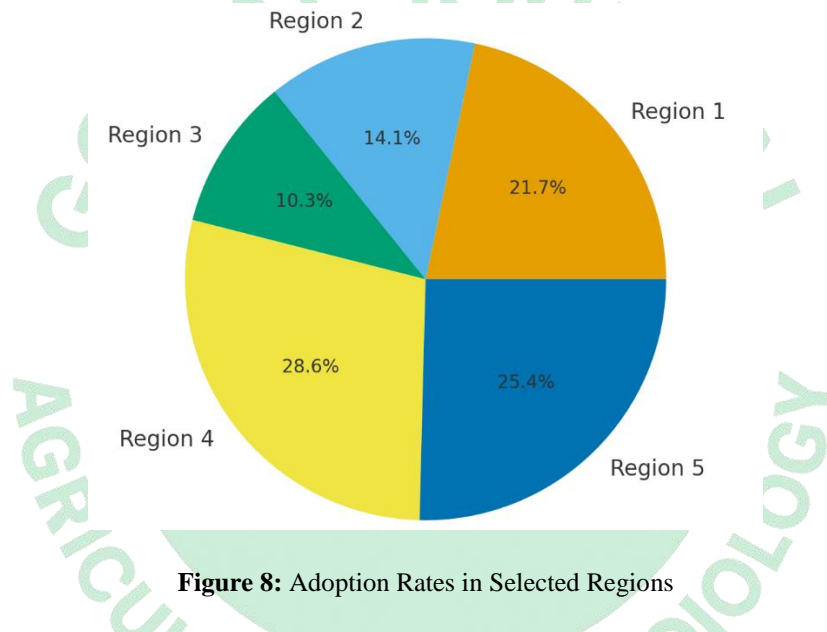
**Figure 5: Compost Nitrogen Content**



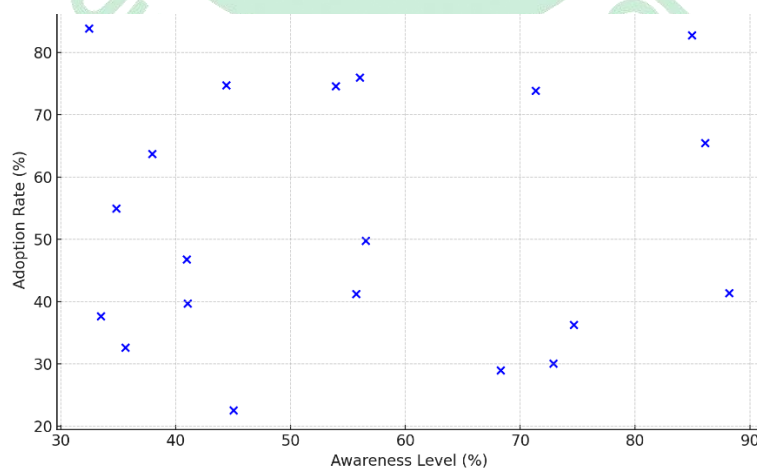
**Figure 6: GHG Reduction by Technology**



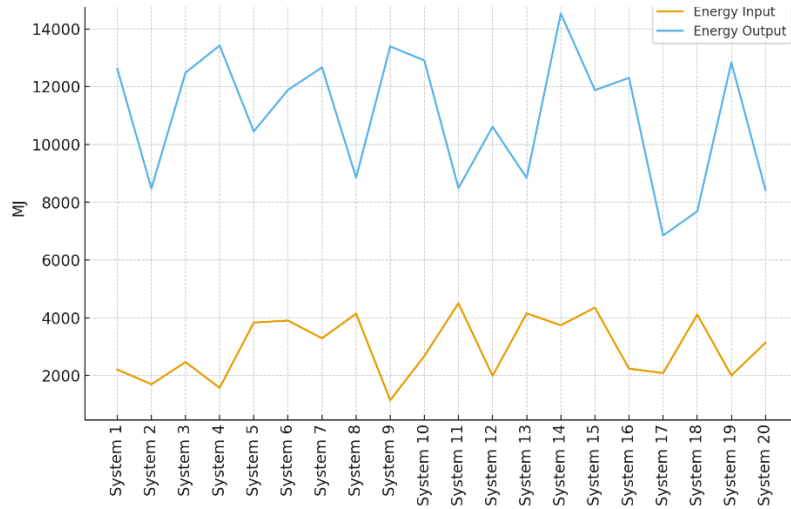
**Figure 7: Production Cost vs Market Price**



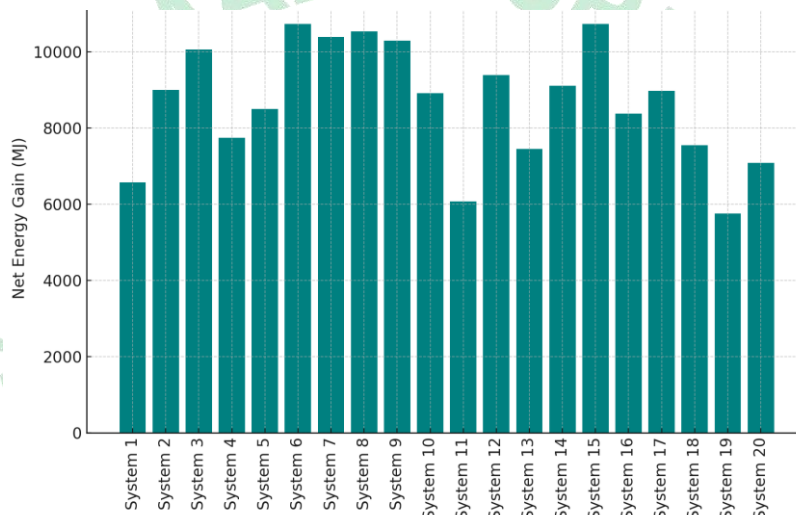
**Figure 8: Adoption Rates in Selected Regions**



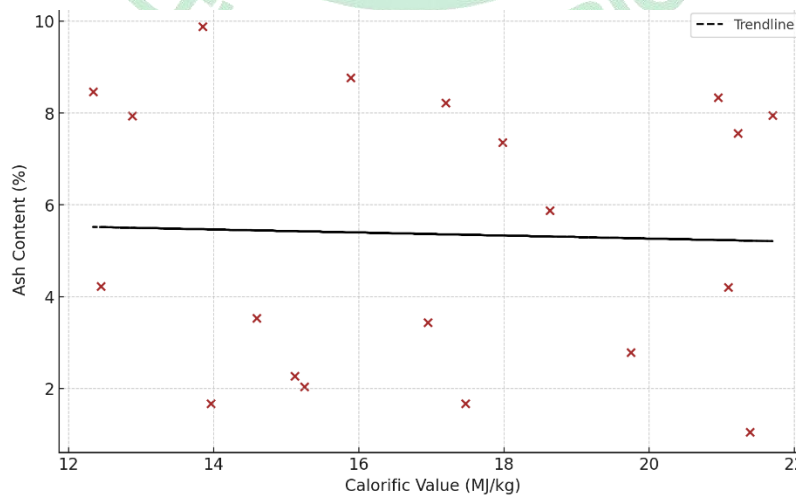
**Figure 9: Awareness vs Adoption**



**Figure 10:** Energy Input vs Output in Systems



**Figure 11:** Net Energy Gain of Systems



**Figure 12:** Calorific Value vs Ash Content

## DISCUSSION

The findings of the analyzed work justify the fact that the valorization of agricultural waste is a viable strategy of putting the ideas of the circular bioeconomy into practice. Laboratory tests demonstrated that technically it is possible to convert crop waste and manure into renewable energy products such as biogas and biochar. Qualitative evaluations indicated that the process was well perceived by the stakeholders, but also there were social and economic issues. Together with these data, one can conclude that circular bioeconomy practices can enhance energy security, environmental protection, and assist rural regions simultaneously, which is consistent with the global sustainability objectives. Among the primary accomplishments of the study, it is possible to mention the demonstration of the fact that waste-to-energy systems can be beneficial in a variety of ways simultaneously. The anaerobic digestion tests revealed that more than enough methane was generated, and this implied that biogas may be a valid renewable substitute to fossil fuels in rural energy blends. There is also the digestate produced as a result of this which is a nutrient-rich organic fertilizer that aids the flow of nutrients within the agricultural systems. This is also in line with the large body of literature that valorization systems are most effective when designed to deliver multifunctional benefits, combining energy recovery with soil fertility benefits (Vasco-Correa et al., 2021). The study highlights the critical role of biochar that is created through pyrolysis that not only enhances soil fertility, but also assists in sequestration of carbon in the long term. The production of biochar assists in combating climate change by ensuring carbon is stored in long term stable forms. This is on top of its secretarial advantages to the agricultural sector. It has been demonstrated in the past that the introduction of

biochar to the soil system can significantly reduce the net greenhouse gas emissions and simultaneously enable crops to produce better (Abiven et al., 2019). Our findings contribute to the available literature since they demonstrate that agricultural residues can be utilized as a soil amendment and as a method of controlling carbon. Although the outcomes are favourable, there are challenges to adoption. The stakeholder interviews revealed that the stakeholders are interested in valorization technology, yet the factors affecting its use among farmers such as deficient infrastructure, absence of technical know-how and excessive initial cost make it less probable that farmers will adopt them. This aligns with the findings of Sanz-Hernandez et al. (2019), who argue that such factors as socio-economic and institutional performance are as significant as technical performance in determining the effectiveness of bioeconomy activities. Without supportive structures, the distance between new concepts in the laboratory and their application in practice will not decrease. Therefore, capacity building, financial incentives, and local participation should matter the most when planning the policies and programs. It is also revealed by the results that the second significant element is that waste valorization must be as well included in existing systems of agriculture and energy. Circular bioeconomy approaches must be integrated within a larger food, water, and energy system that is both environmental friendly and does not view trash as a distinct resource. In a decentralized, as Lopes et al. (2022) note, the addition of agricultural leftovers to the energy infrastructure and the soil management process can deliver synergistic effects in various industries. Our study supports this systems perspective through showing how energy efficiency of recovery, soil fertility enhancement and livelihoods of farmers are interconnected. Another thing that is revealed in the

discussion is the need to adapt to the situation. The diversity of agricultural systems across regions implies that the single solution to waste valorization could not be applied. Availability of local feedstock, cultural practice, and market conditions should be used to determine the choice of valorization technology. König et al. (2021) emphasize the importance of designing transitions to a circular bioeconomy that aligns to the requirements of individual regions yet tries to achieve the goals of sustainability as an overall whole. Our qualitative results attest to this point by demonstrating that farmers can only accept something that is cost-effective and culturally acceptable. Conclusively, the findings indicate that the conversion of the agricultural waste into a useful activity is not only a technical activity, but a transformation in society and technology. All the scientists, legislators, industry and farmers should collaborate to create places where innovations will develop in a sustainable manner. The gap between theoretical bioeconomy models and practical applications is bridged by this work, that is, by combining experimental validation and stakeholder interaction. By so doing, it provides concrete examples and practical information to make agriculture more bioeconomically circular.

## CONCLUSION

This analysis demonstrated that utilizing agricultural waste to create something practical is one of the primary methods to advance the circular bioeconomy and at the same time address the issues of resource efficiency, energy security, and environmental sustainability. In the study, both experimental and qualitative methods were adopted to confirm that agricultural wastes, which include but are not limited to, crop straws, husks, and livestock manure, can be successfully converted to renewable sources of energy, such as biogas, and

value-added products, such as biochar. The quantitative analyses indicated that anaerobic digestion generated significant quantities of methane and that biochar could enhance soil fertility indicating that either of the two processes can be adopted to restore energy and help in sustainable agriculture. This, in conjunction with the qualitative evaluation revealed that farmers are keen on using waste-to-resource technologies provided they possess the appropriate infrastructures, financial incentives, and technical training. The findings highlight the importance of multi-stakeholder teamwork in an attempt to bridge laboratory-level innovations and community-level implementation. The fusion of techno-economic viability and socio-environmental perspectives reveal that transforming agricultural waste into something useful is not only a technical success; it is also an opportunity to alter the path of the rural development. To sum up, the potential of circular bioeconomy models in the agricultural sector is high in reducing greenhouse gas emissions, becoming more energy independent, enhancing the health of soil, and resilient communities. It will be time that policy makers, researchers and practitioners come together to create the enabling structures that will see more solutions being adopted with rapidity, so that agricultural systems can move beyond linear, waste generating systems to closed-loop, regenerative and future facing systems.

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