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Anaerobic Digestion of Cassava Root: Biogas, Nutrient Content and Cyanide Considerations

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Cassava (*Manihot esculenta*) is one of the world's most important root crops and is grown throughout tropical and subtropical regions. Cassava is best known as a staple food. Its high carbohydrate content also makes it well suited for anaerobic digestion, producing both renewable energy and nutrient-rich digestate. While cassava/cassava waste is a promising substrate for anaerobic digestion, the presence of cyanogenic glycosides means that cyanide behavior remains an important consideration.

Biochemical Methane Potential (BMP)

The BMP analyses were conducted using the AMPTS II equipment (Figure 1) (Bioprocess Control, Lund, Sweden) at Novia University of Applied Sciences. The tests were performed in accordance with VDI 4630 (VDI 4630, 2006) and published studies (Raposo et al., 2011; Angelidaki et al., 2009). BMP analysis is performed to assess the biogas production potential of a substrate.

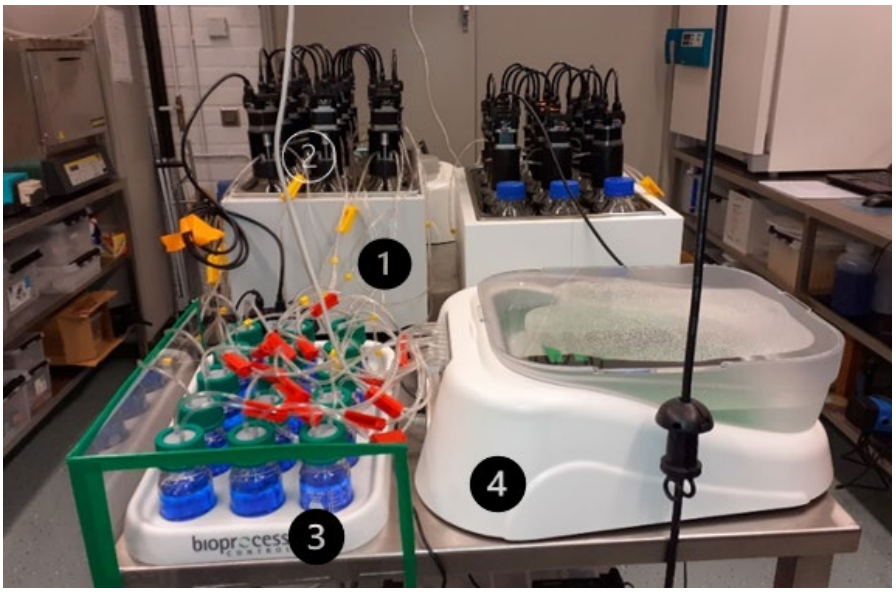

Figure 1. *Automatic Methane Potential Test System II (AMPTS®II) equipment.*
1. Thermostatic water bath,
2. Glass bottles with motor-driven stirrers,
3. CO2 traps,
4. Gas meter unit.

The substrate-mixtures were of fresh or dried cassava root mixed with inoculum from household organic waste at the Stormossen biogas plant. BMP assay was conducted over 49 days, with all substrates, blanks, and cellulose reference in triplicate.

The study also examined the nutrient composition of the cassava root and the digestates (Table 1). Cassava roots were found to contain high levels of carbon but relatively low concentrations of nitrogen. This resulted in very high carbon-to-nitrogen (C/N) ratios (Table 1) indicating an abundance of carbon but insufficient nitrogen for optimal anaerobic digestion. While a high carbon content is beneficial for methane production, low nitrogen levels can limit microbial activity. The optimal bioavailable C/N ratio for anaerobic digestion is generally considered to be between 20 and 30, supporting efficient microbial growth and metabolic activity. Co-digesting cassava waste with nitrogen-rich organic residues such as manure, food waste, or other organic residues are recommended.

Table 1. *Nutrient content of cassava root, inoculum and resulting digestates after anaerobic digestion.*

Substrate, digestate	Dry matter (%)	Total nitrogen (g/kg DM)	Nitrogen % of DM	Phosphorus (g/kg DM)	Phosphorus % of DM	Total carbon g/kg DM	Carbon % of DM	C/N ratio	N/P ratio
Cassava root/ peeled, dried	88	1,6	0,16	0,5	0,05	450	45	280	3,2
Cassava root/ unpeeled, fresh	32	3,3	0,33	0,9	0,09	420	42	130	3,7
Inoculum Stormossen	3,2	52	5,2	7,6	0,76	370	37	7,1	6,8
Digestate 1 dry cassava + inoculum	2,9	55	5,5	8,5	0,85				6,5
Digestate 2 fresh cassava + inoculum	2,8	56	5,6	8,1	0,81				6,9
Digestate 3 inoculum	2,5	52	5,2	9,4	0,94				5,5

The flow rate was highest during the first days of digestion and then declined rapidly, indicating that most biodegradable organic matter was converted early in the process. Due to saturation of the NaOH CO_2 traps in some of the reactors, methane production data for fresh cassava and cellulose were corrected before BMP values were calculated. Both fresh and dried cassava roots exhibited moderate methane yields (Figure 2). The dried cassava root produced slightly higher BMP values than the fresh cassava root. However, the

overlapping error bars indicate that this difference should be interpreted with caution. Cellulose was used as a control substrate, and its BMP result confirmed the activity of the inoculum and the suitability of the experimental conditions for methane production. These findings demonstrate that cassava root can be a promising substrate for biogas production. Although further research is needed to investigate the effects of pretreatment, particle size, and co-digestion strategies for optimizing methane yields.

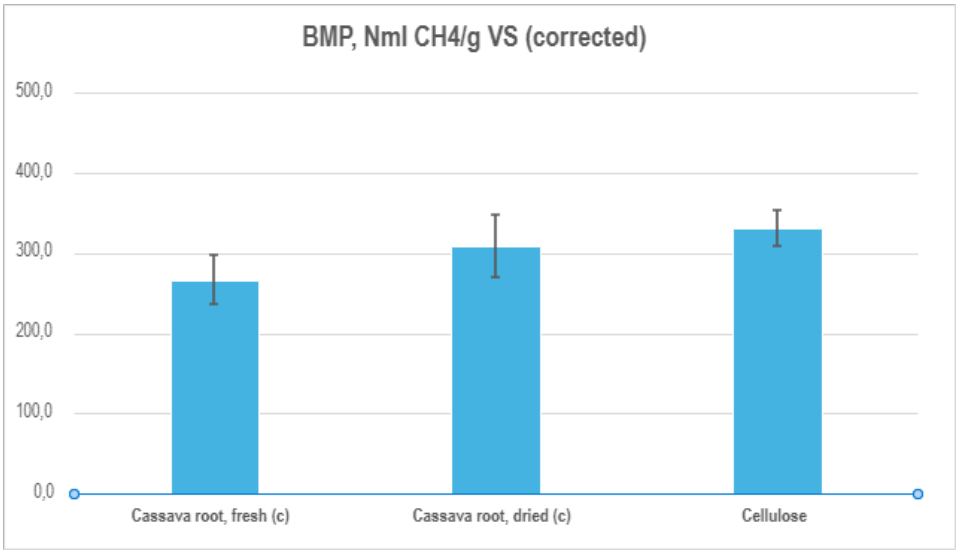

Figure 2. *Corrected BMP for fresh cassava root, dried cassava root, and cellulose. Error bars represent the standard deviation of triplicate measurements.*

More Than Energy: A Valuable Fertilizer Product

The study also examined the nutrient composition of cassava roots and the digestates produced. Nitrogen, phosphorus, and potassium concentrations were considerably higher in the digestates than in the original cassava roots, largely due to the contribution of the inoculum used in the process, Figure 3.

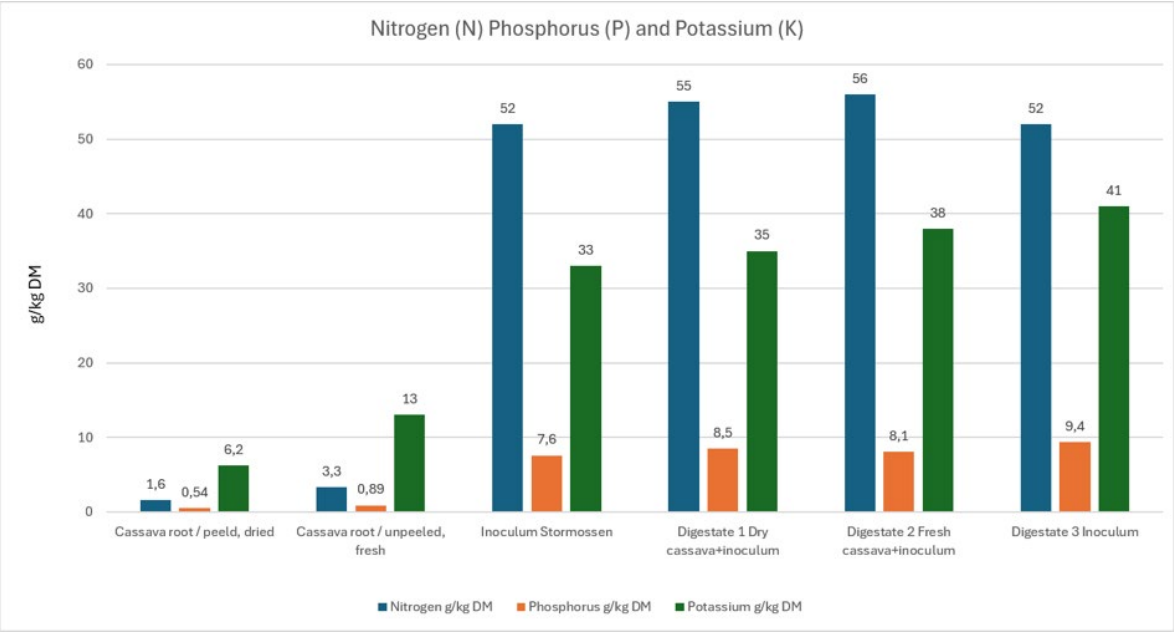

Figure 3. *Nitrogen (N), phosphorus (P), and potassium (K) concentrations in cassava roots, inoculum, and digestates.*

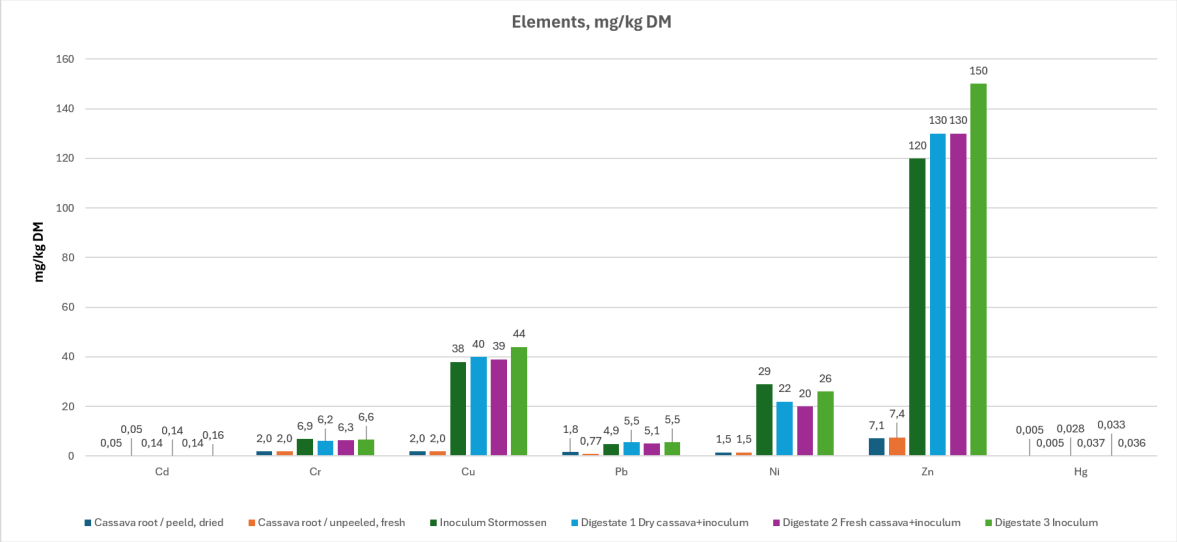

Figure 4. *Concentrations of selected elements in the substrates and digestates.*

Figure 4 shows that the digestate composition was largely determined by the inoculum, as cassava roots contained only low concentrations of trace elements. Zinc, copper, and chromium were the most abundant elements detected, and all analysed concentrations remained below the Finnish regulatory limits for organic soil improvers (Finlands författningssamling, 2025).

Cyanide Remains an Important Research Question

One of the challenges associated with cassava is its content of cyanogenic compounds, which can release cyanide during degradation. Cyanide is known to inhibit microbial activity and can potentially interfere with biogas production. (Kpata-Konan et al., 2018)

Cyanide concentrations were determined using an elevated limit of quantification due to the complex matrix of the samples. Analyses were conducted according to *SFS-EN ISO 14403-2:2012* using continuous flow analysis (CFA). It should be noted that this analytical method is accredited for water samples but was not accredited for the substrate and digestate matrices investigated in this study.

Cyanide concentrations in both the cassava substrates and the resulting digestates were below the analytical detection limits under the conditions investigated. However, the elevated detection limits, the use of a non-accredited analytical method and the complex composition of the samples prevent definitive conclusions regarding the presence of residual cyanide or its degradation during the digestion process. Consequently, the results do not demonstrate complete cyanide degradation, nor do they confirm the absence of cyanide in either the substrates or the digestates. Rather, they indicate that any cyanide present was below the quantification range of the analytical method employed. Further analyses using standardized methods are required to verify cyanide removal and to reliably assess the safety of the resulting digestate.

Conclusions

Cassava/cassava waste has potential as a substrate for anaerobic digestion because of its high carbohydrate content. Given the suboptimal carbon-to-nitrogen (C/N) ratio of cassava, future studies should focus on pretreatment methods and co-digestion approaches to optimize nutrient balance, enhance methane production, and improve overall digestion performance. Uncertainties remain regarding the degradation of cyanogenic compounds and the fate of cyanide during anaerobic digestion, highlighting the need for additional studies to ensure the safe and sustainable utilization of cassava in biogas production.

References

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