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Closing the loop in agricultural waste management: co-smouldered digestate ash as alkalinity and trace element supplement for anaerobic digestion

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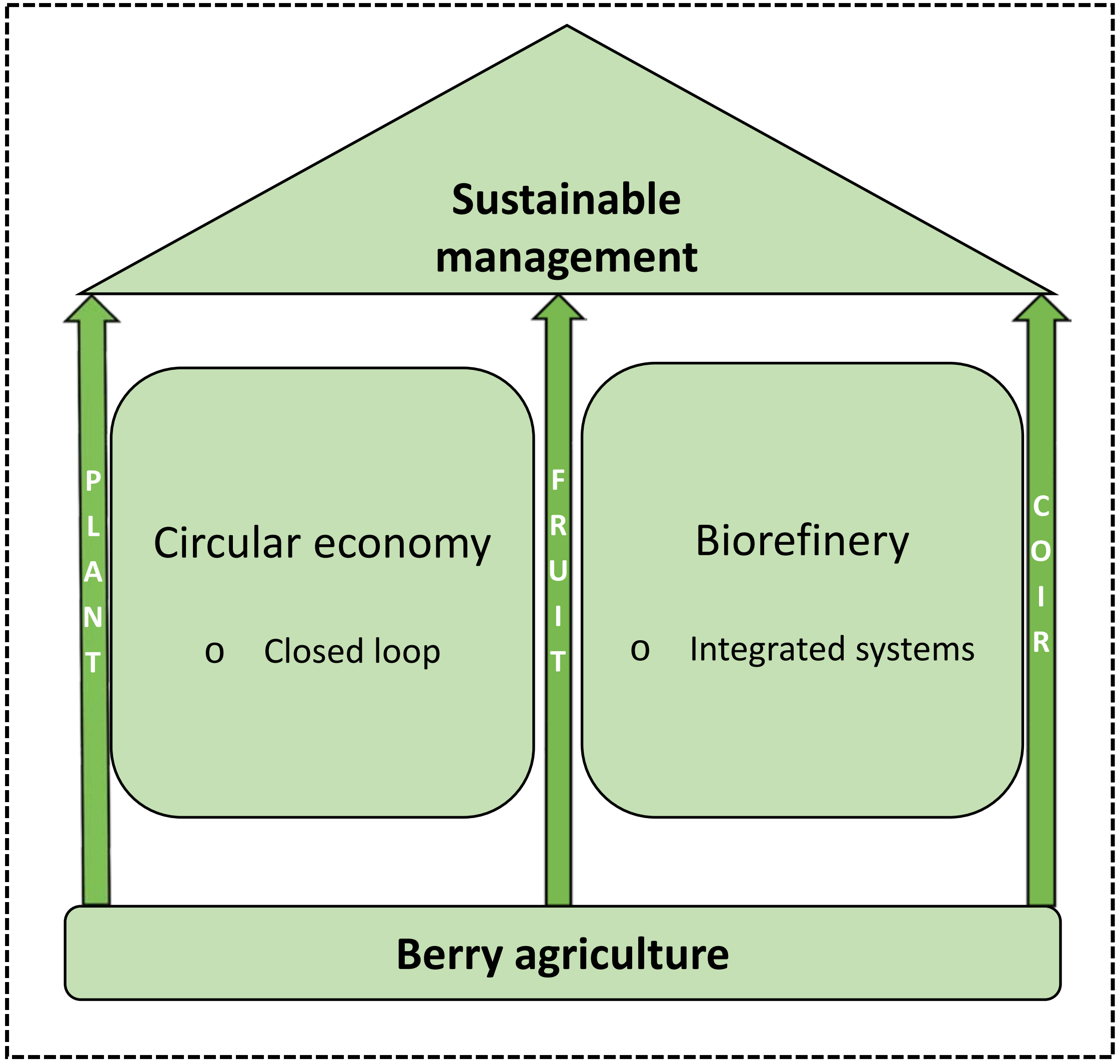
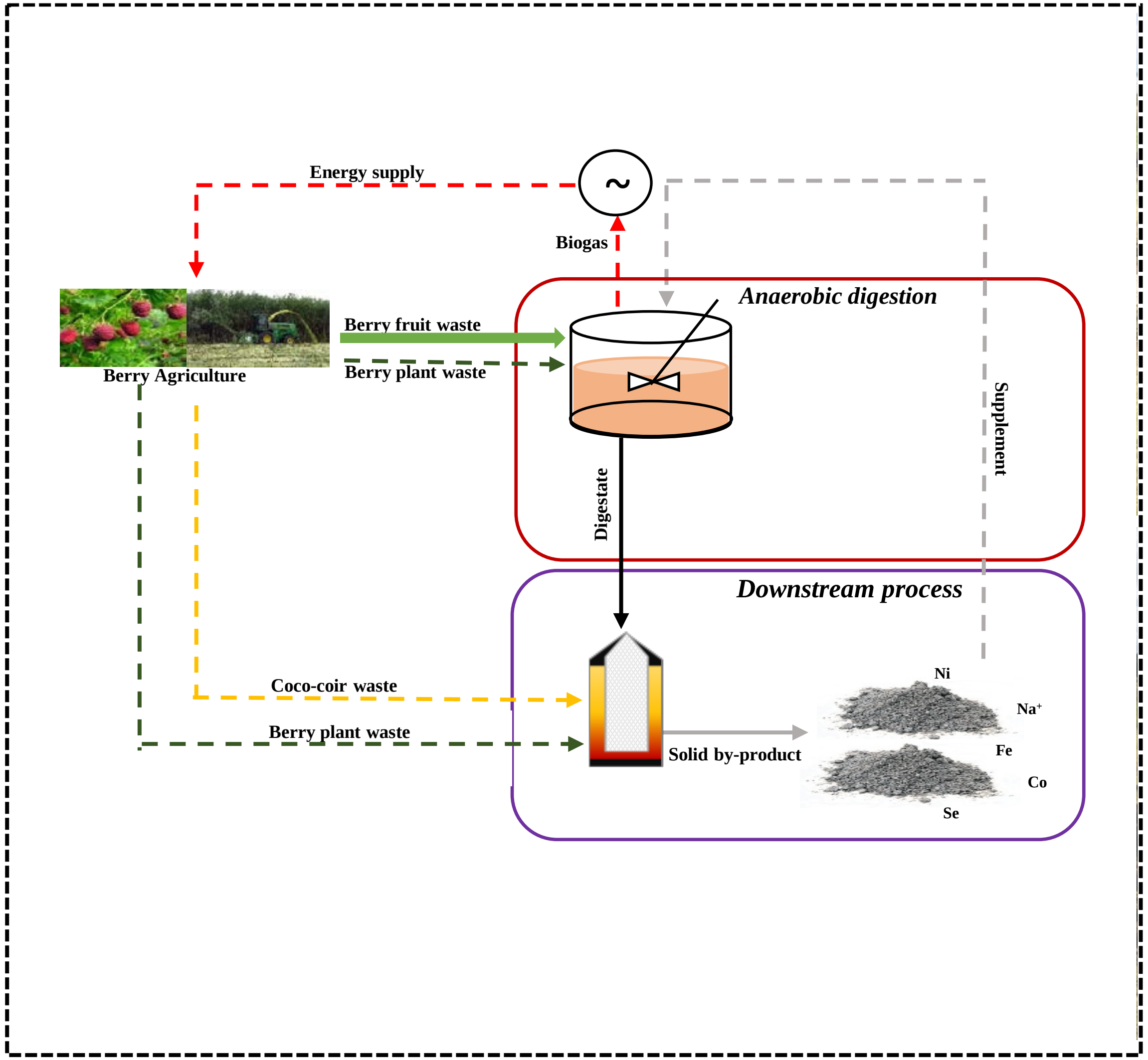
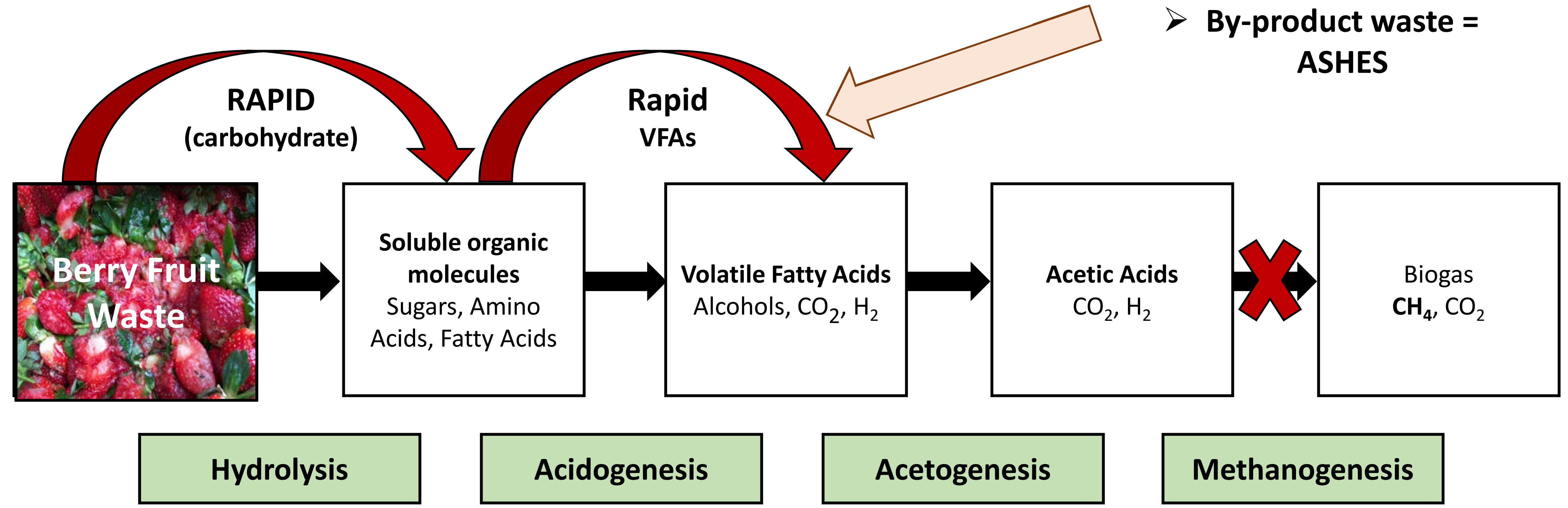
Introduction: Project background & Context

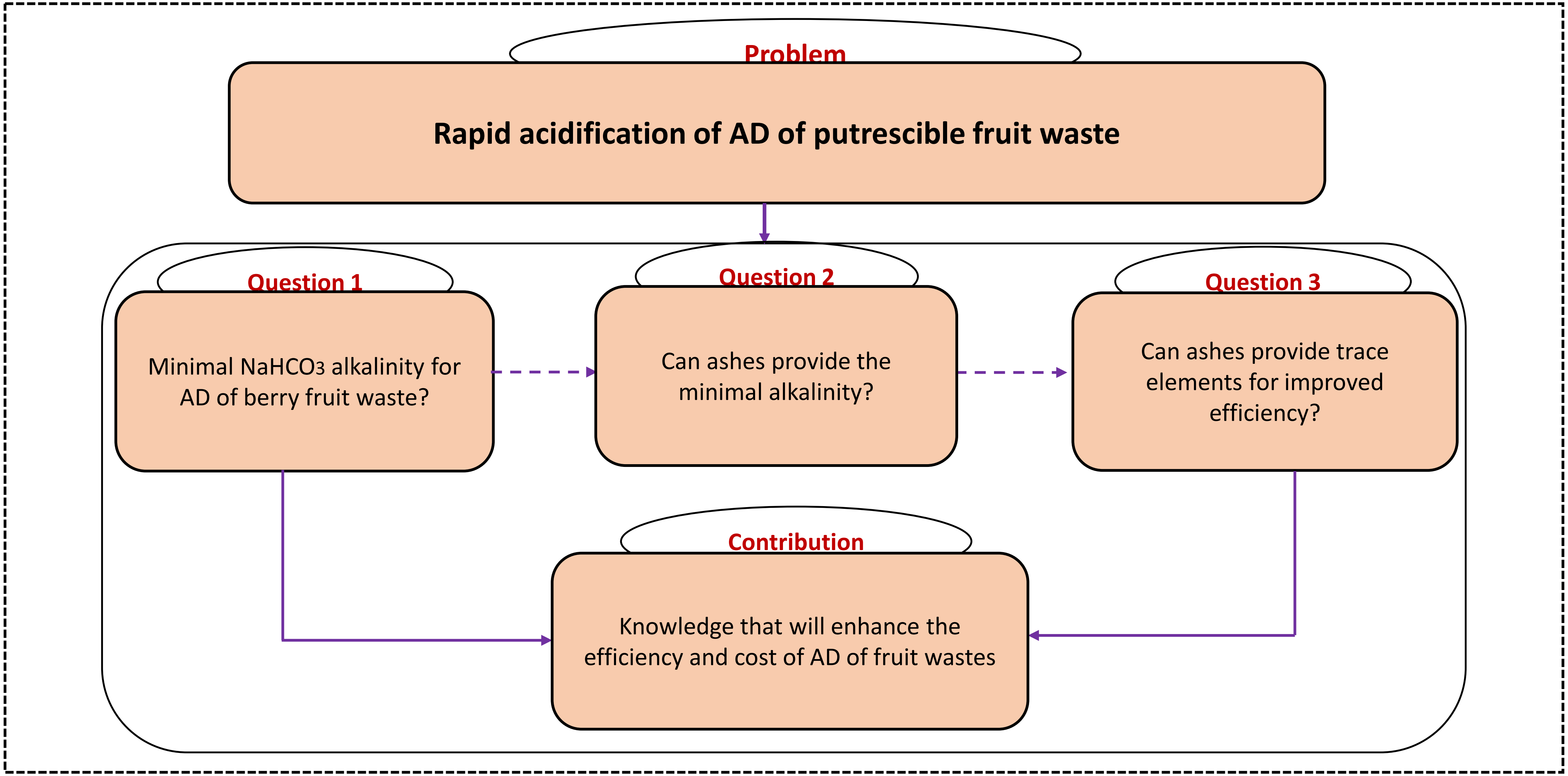




Introduction: Berry Fruit Waste Anaerobic digestion limitation



Research Needs & Questions



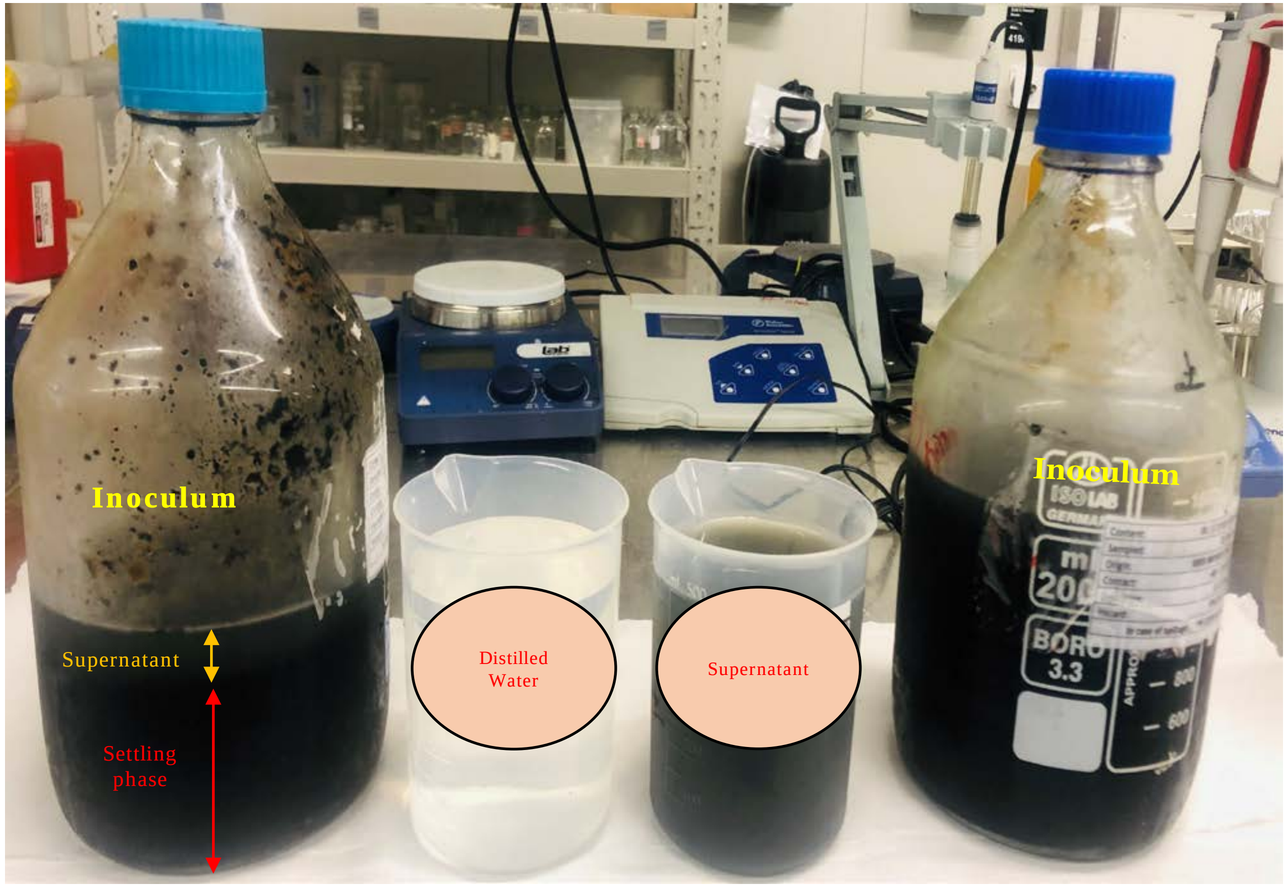
Materials and methods

❑ Inoculum

➢ Anaerobic microbial inoculum are granular sludge collected from an UASB industrial wastewater treatment plant of the XXXX Brewery Company located in Brisbane, Australia.

❑ Preparation

➢ To replicate a continuous AD process, the inoculum was prepared by decanting and replacing the supernatant with an equal volume of fresh distilled water, after a settling phase.



Materials and methods

❑ Substrate

- ➢ The substrate was berry fruit waste (BFW) collected from Sunny Ridge® farm located in the Caboolture region, Queensland, Australia.
- ➢ Ground and stored (-9.4ºC) to avoid undesired fermentation.

❑ Smouldering Ashes

- ➢ Ashes were obtained from an experimental smouldering system of a mixture of 73% coco-coir waste and 27% digestate from anaerobic digestion of berry fruit and plant waste.

Berry Fruit

Berry Plant

DIGESTATE

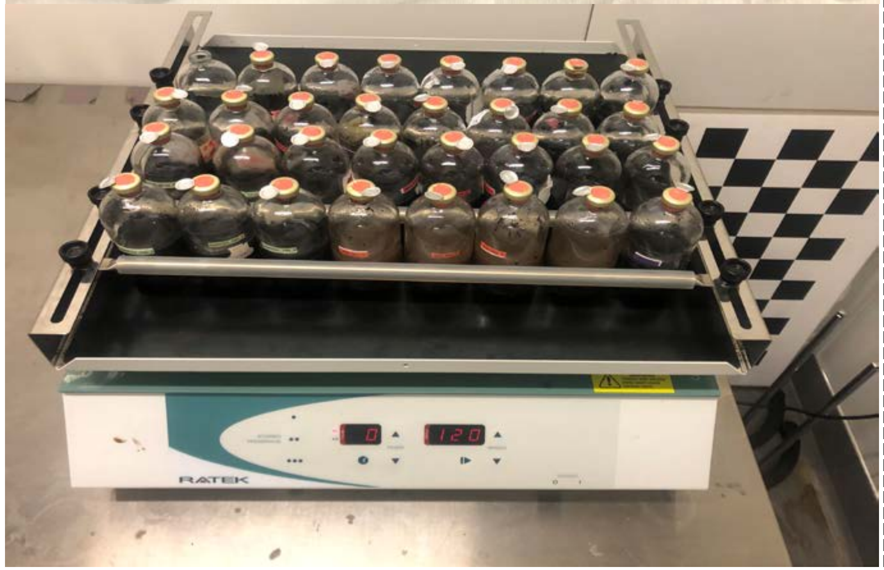
COIR

Ashes

Materials and methods

❑ Biomethane Potential (BMP) Assays

- Series of triplicate BMP assays were performed in batch systems using serum bottles (160 mL)
- inoculum /substrate ratio was 2:1, in volatile solids (VS).
- Mesophilic conditions (35 ± 0.5 ºC)

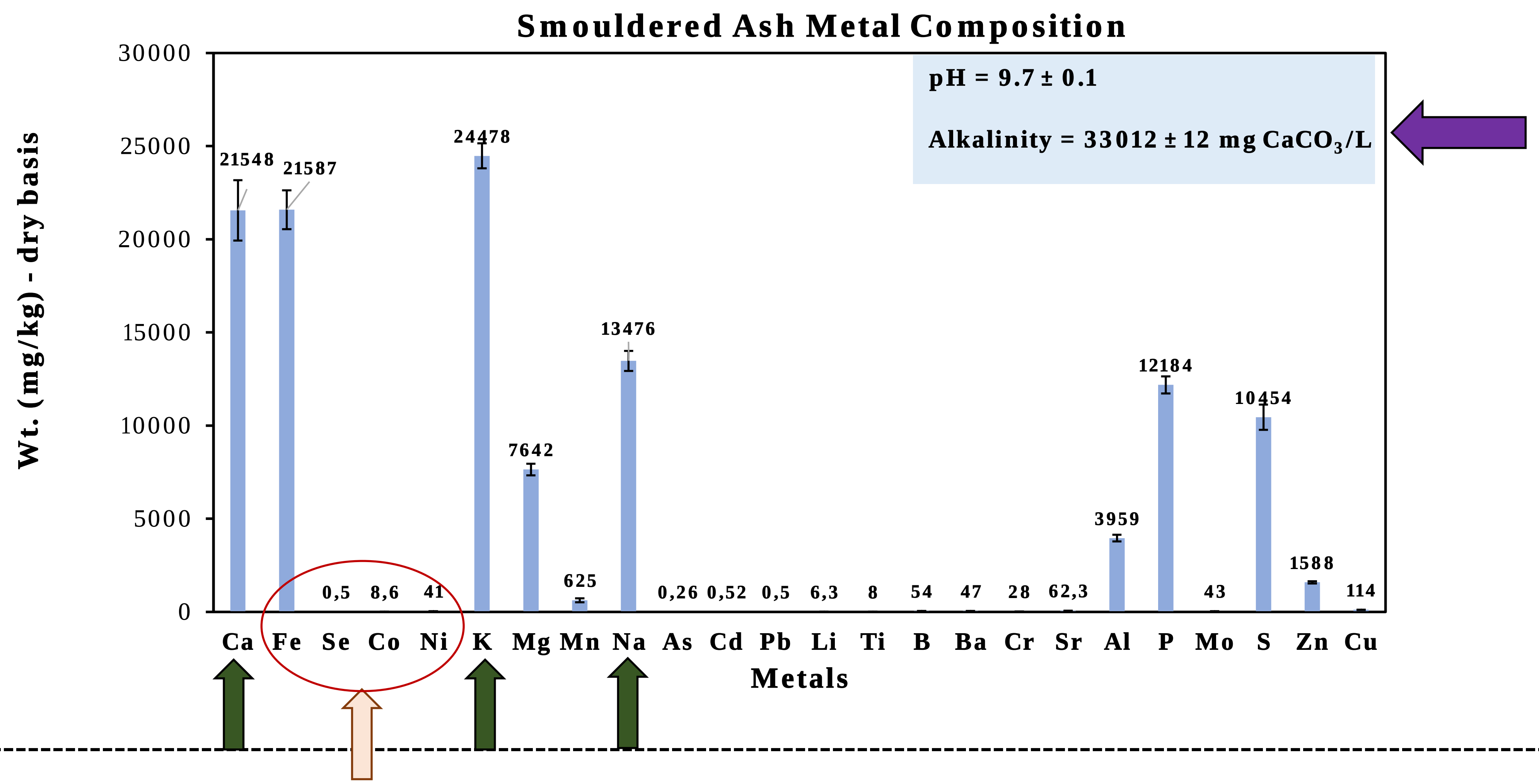


❑ Assays and controls

- Alkalinity required for the stable anaerobic digestion of berry fruit waste with $NaHCO_3$ as alkalinity buffer (0 alkalinity)
- The effect of ashes as a source of alkalinity (Test with $NaHCO_3$)
- The effect of ashes as TE source (Test with $NaHCO_3$)

Materials and methods

❑ Ash analytical characteristics



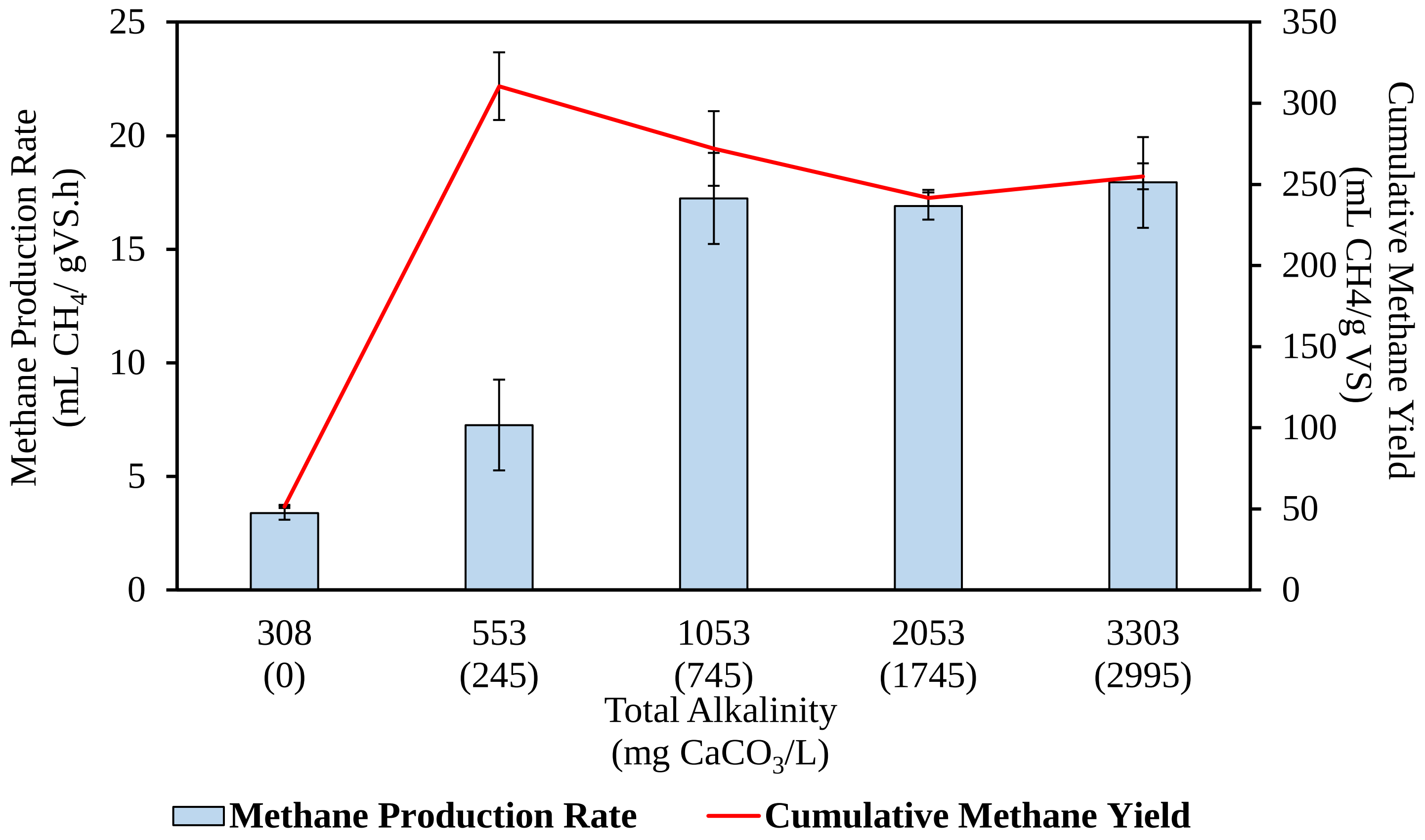
Research outcome

RESULTS

Results

Question 1: What is the minimal $NaHCO_3$ alkalinity required for AD of Berry Fruit Waste?

Methane yield and rate from the BMP of BFW at range of total alkalinity concentration from $NaHCO_3$.



Results

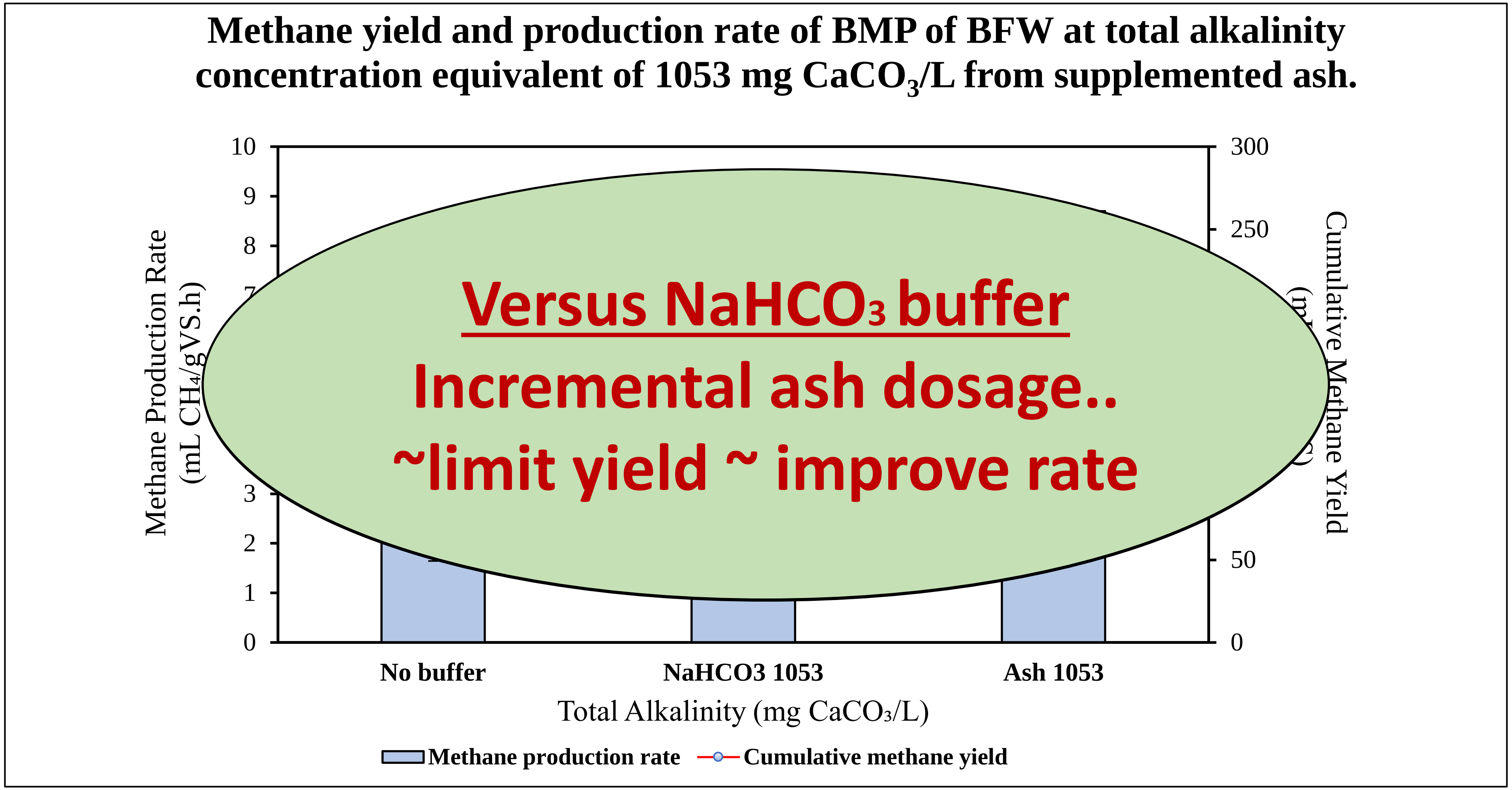
Question 1: What is the minimal $NaHCO_3$ alkalinity required for AD of Berry Fruit Waste?

Total alkalinity (mg $CaCO_3$/L)	**308**	553	**1053**	2053	3303
Added $NaHCO_3$ (mg $CaCO_3$/L)	**0 (control)**	245	**745**	1745	2995
Biogas composition					
CH_4 content (%)	[illegible]	[illegible]	…1	59.3 ± 0.1	59.5 ± 1.5
CO_2 content (%)	[illegible]	[illegible]	[illegible]	…4 ± 0.1	40.0 ± 0.9
N_2 content (%)	[illegible]	[illegible]	[illegible]	[illegible]	0.4 ± 0.4
O_2 content (%)	[illegible]	[illegible]	[illegible]	[illegible]	<D.L.
Effluent characterization					
pH	[illegible]	[illegible]	[illegible]	[illegible]	7.8 ± 0.1
IA/PA ratio	[illegible]	[illegible]	[illegible]	…23 ± 0.04	0.19 ± 0.05
Alkalinity (mg $CaCO_3$/L)	[illegible]	[illegible]	… ± 72	3375 ± 375	3167 ± 577
sCOD (mg O_2/L)	**4637 ± 259**	129 ± 136	**81 ± 4**	82 ± 4	92 ± 3
Acetic acid (mg O_2/L)	**1304 ± 66**	3 ± 1	**n.d.**	n.d.	n.d.
Propionic acid (mg O_2/L)	**130 ± 14**	<D.L.	**n.d.**	n.d.	n.d.
Butyric acid (mg O_2/L)	**1390 ± 59**	<D.L.	**n.d.**	n.d.	n.d.
Valeric acid (mg O_2/L)	**337 ± 28**	2 ± 1	**n.d.**	n.d.	n.d.
Hexanoic acid (mg O_2/L)	**99 ± 11**	<D.L.	**n.d.**	n.d.	n.d.

Minimal Alkalinity
1053 mg $CaCO_3$/L
(745 mg/L $CaCO_3$ dosed)

Results

Question 2: Can the required alkalinity for AD of fruit waste be provided by smouldering ashes?



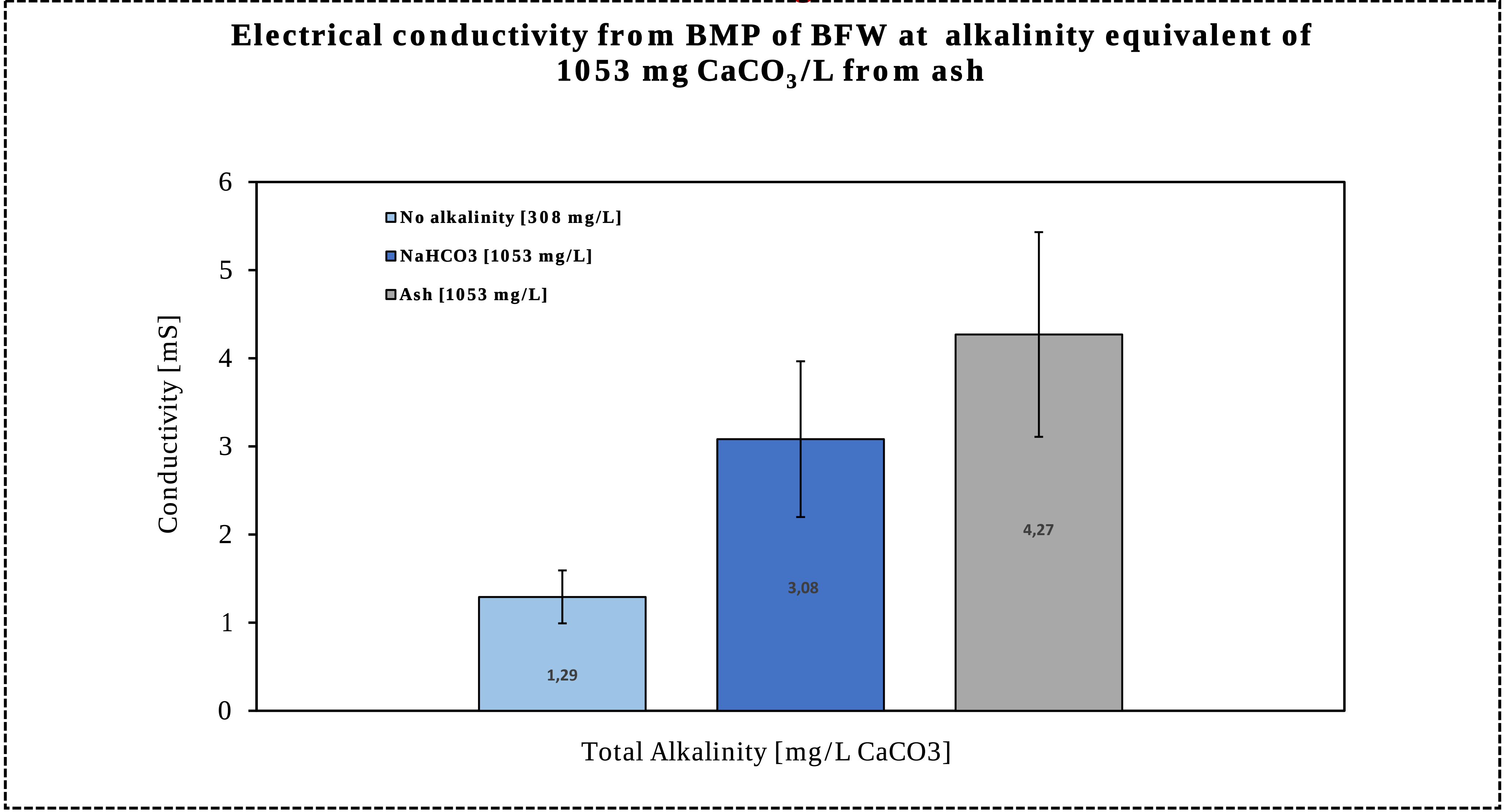
Results

Question 2: Can the required alkalinity for AD of fruit waste be provided by smouldering ashes?

Total alkalinity (mg $CaCO_3$/L)	308	1053	**1053**
Added $NaHCO_3$ (mg CaCO3/L)	0	745	**0**
Added Ashes (mg $CaCO_3$/L)	0	0	**745**
Biogas composition			
CH_4 content (%)	61.7 ± 3.6	64.6 ± 0.4	**67.9 ± 0.3**
CO_2 content (%)	38.1 ± 3.6	**35.4 ± 0.4**	**32.1 ± 0.3**
N_2 content (%)	0.2 ± 0.0	**<D.L.**	**<D.L.**
O_2 content (%)	<D.L.	**<D.L.**	**<D.L.**
Effluent characterization			
pH	5.3 ± 0.2	**7.5 ± 0.1**	**7.9 ± 0.1**
IA/PA ratio	>D.L.	**0.38 ± 0.03**	**0.46 ± 0.07**
Alkalinity (mg $CaCO_3$/L)	469 ± 63	**2268 ± 28**	**5421 ± 233**
sCOD (mg O_2/L)	4426 ± 471	**293 ± 12**	**270 ± 14**
Acetic acid (mg O_2/L)	1266 ± 93	**4 ± 1**	**4 ± 0**
Propionic acid (mg O_2/L)	134 ± 15	**1 ± 0**	**1 ± 0**
Butyric acid (mg O_2/L)	1290 ± 228	**1 ± 0**	**1 ± 0**
Valeric acid (mg O_2/L)	345 ± 30	**1 ± 0**	**1 ± 0**
Hexanoic acid (mg O_2/L)	85 ± 29	**<D.L.**	**<D.L.**

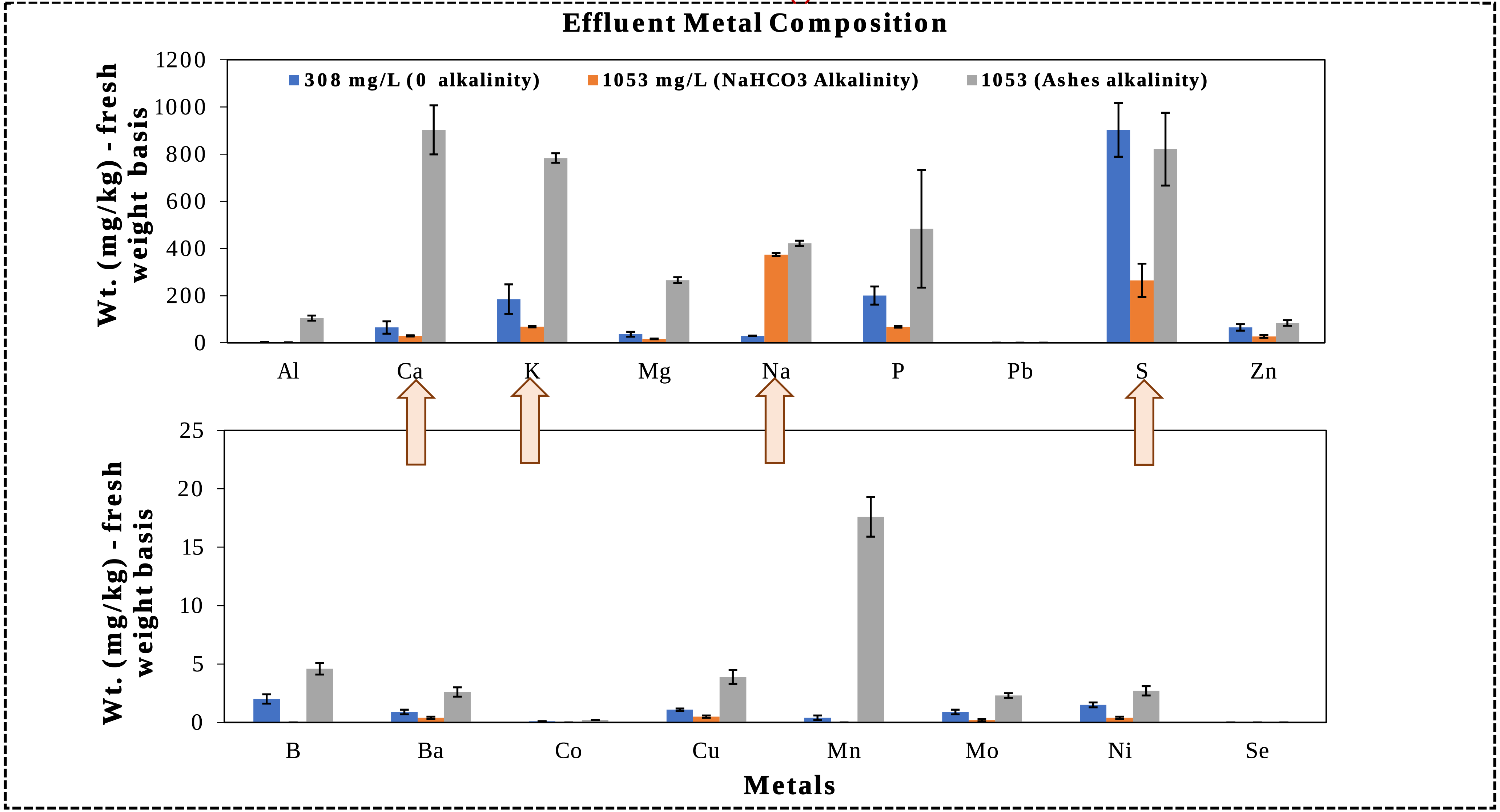
Results

Question 2: Can the required alkalinity for AD of fruit waste be provided by smouldering ashes?



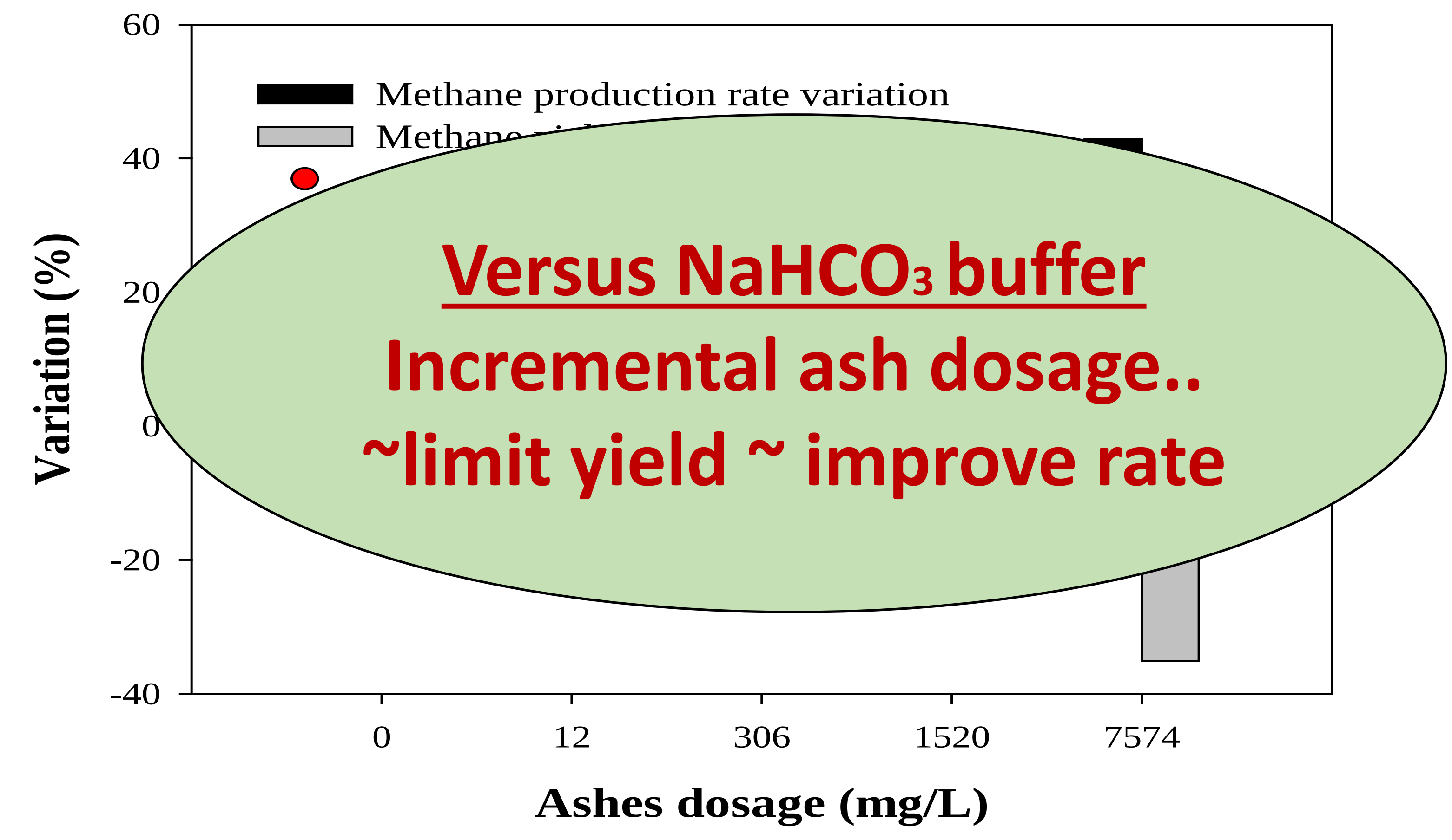
Results

Question 2: Can the required alkalinity for AD of fruit waste be provided by smouldering ashes?



Results

Question 3: Can ashes provide essential trace elements (TEs) to improve the efficiency of AD of fruit waste?



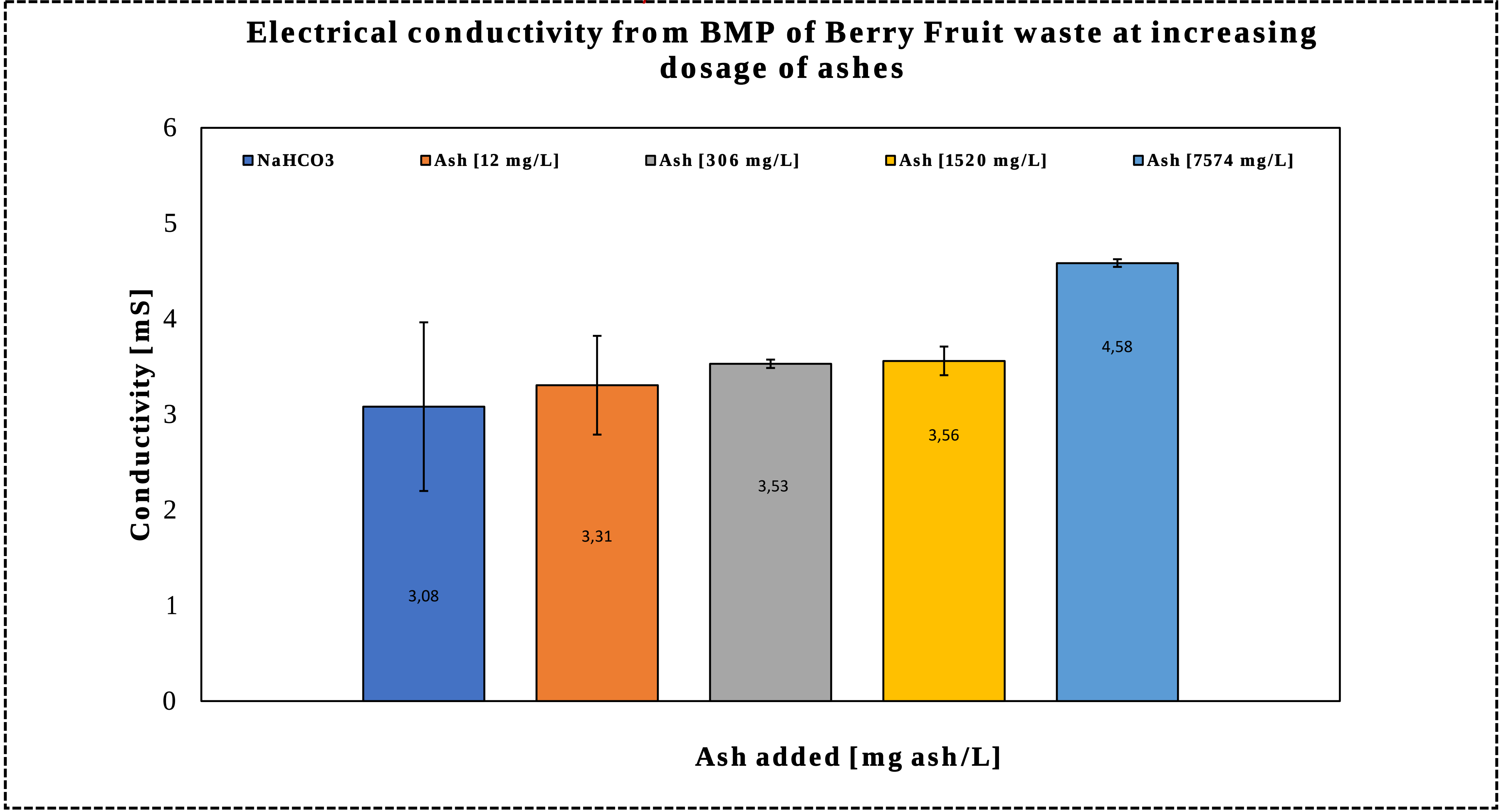
Results

Question 3: Can ashes provide essential trace elements (TEs) to improve the efficiency of AD of fruit waste?

Ash dosage (mg ash/L)	Control	12	306	1520	7574
Biogas composition					
CH_4 content (%)	64.6 ± 0.4	64.0 ± 1.3	63.8 ± 0.4	64.0 ± 0.1	65.0 ± 0.4
CO_2 content (%)	35.4 ± 0.4	36.0 ± 1.3	36.2 ± 0.4	36.0 ± 0.1	35.0 ± 0.4
N_2 content (%)	<D.L.	<D.L.	<D.L.	<D.L.	<D.L.
O_2 content (%)	<D.L.	<D.L.	<D.L.	<D.L.	<D.L.
Effluent characterization					
pH	7.5 ± 0.1	7.41 ± 0.08	7.41 ± 0.01	7.43 ± 0.03	7.67 ± 0.03
Alkalinity ratio (IA/PA)	0.38 ± 0.03	0.24 ± 0.09	0.25 ± 0.06	0.33 ± 0.03	0.43 ± 0.06
Alkalinity (mg $CaCO_3$/L)	2268 ± 104	2435 ± 61	2475 ± 115	2621 ± 165	3925 ± 156
sCOD (mg O_2/L)	293 ± 12	350 ± 8	283 ± 5	243 ± 17	227 ± 21
Acetic acid (mg O_2/L)	4 ± 1	2 ± 0	4 ± 1	4 ± 0	4 ± 0
Propionic acid (mg O_2/L)	2 ± 0	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Butyric acid (mg O_2/L)	1 ± 0	1 ± 0	<D.L.	<D.L.	<D.L.
Valeric acid (mg O_2/L)	1 ± 0	1 ± 1	<D.L.	<D.L.	<D. L.
Hexanoic acid (mg O_2/L)	<D.L.	<D.L.	<D.L.	<D.L.	<D.L.

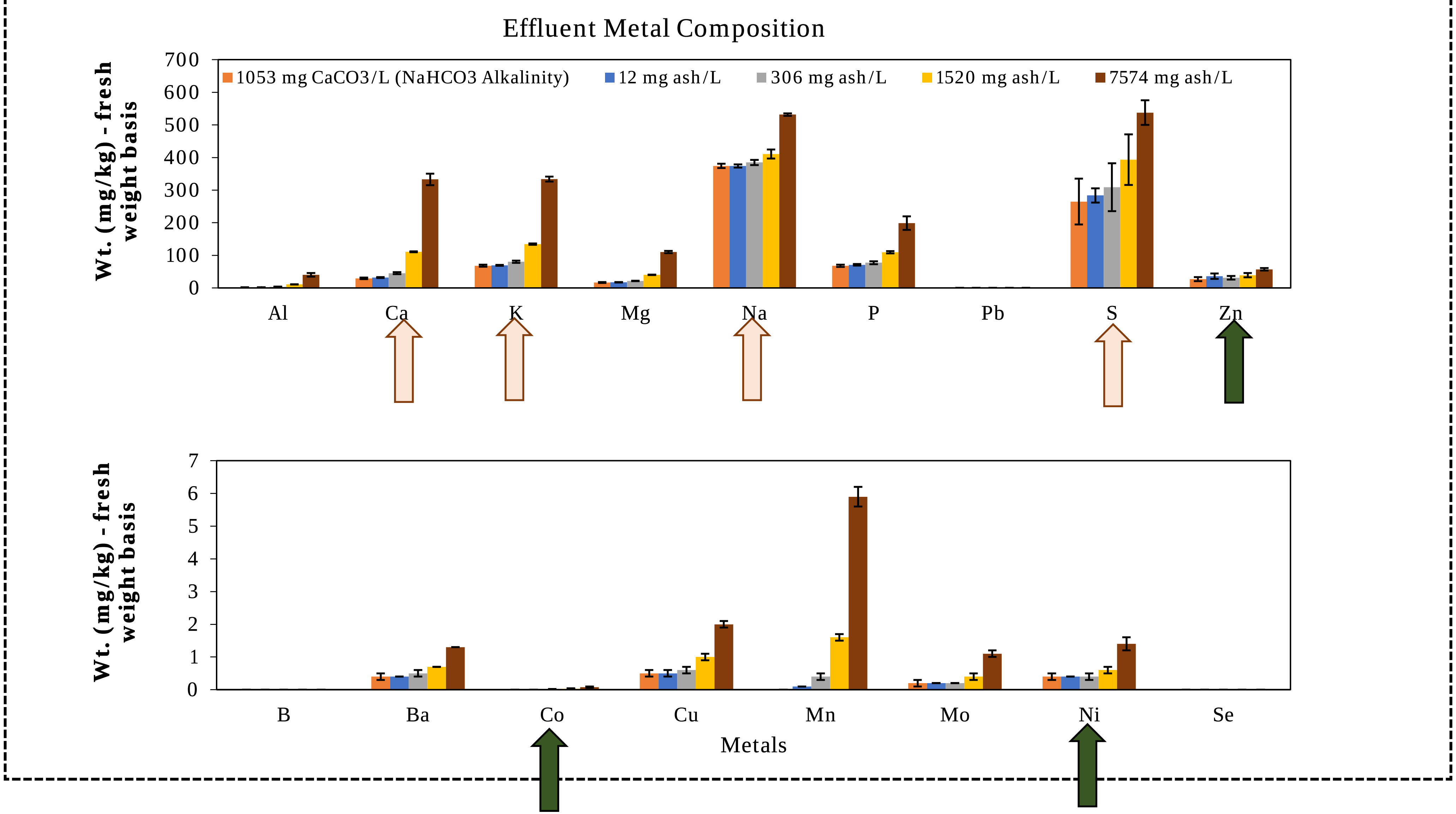
Results

Question 3: Can ashes provide essential trace elements (TEs) to improve the efficiency of AD of fruit waste?



Results

Question 3: Can ashes provide essential trace elements (TEs) to improve the efficiency of AD of fruit waste?



Conclusion

Total alkalinity of 1053 mg/L $CaCO_3$ from dosing 745 mg/L $CaCO_3$ from $NaHCO_3$ provides the minimal alkalinity for berry fruit waste AD

Equivalent total alkalinity (1053 mg/L $CaCO_3$) from dosing co-smouldered digestate ash inhibit methane yield

Compared to AD system with bicarbonate buffer

Equivalent total alkalinity (1053 mg/L $CaCO_3$) from dosing co-smouldered digestate ash enhanced production rate

In an already buffered system, incremental addition of co-smouldered digestate ashes as TEs source inhibits the methane yield but enhances methane production rate

Conclusion

Minimal total alkalinity (1053 mg/L $CaCO_3$) from dosing co-smouldered digestate ash enhanced methane yield

Compared to AD system with no added buffer

Minimal total alkalinity (1053 mg/L $CaCO_3$) from dosing co-smouldered digestate ash enhanced production rate

Conclusion

When reactor volume reduction dominates the economics of the AD system deployment, co-smouldered digestate ash could be an effective inexpensive material for replacement of synthetic ($NaHCO_3$) buffers in AD of berry fruit waste. Thus, could enhance the economic and technical feasibility of integrating AD and smouldering for closed loop management of berry agricultural residues.

Thank you for your time …

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