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Multivariate Analysis on Food Waste Characteristic to Cumulative Biogas Yield during Anaerobic Digestion

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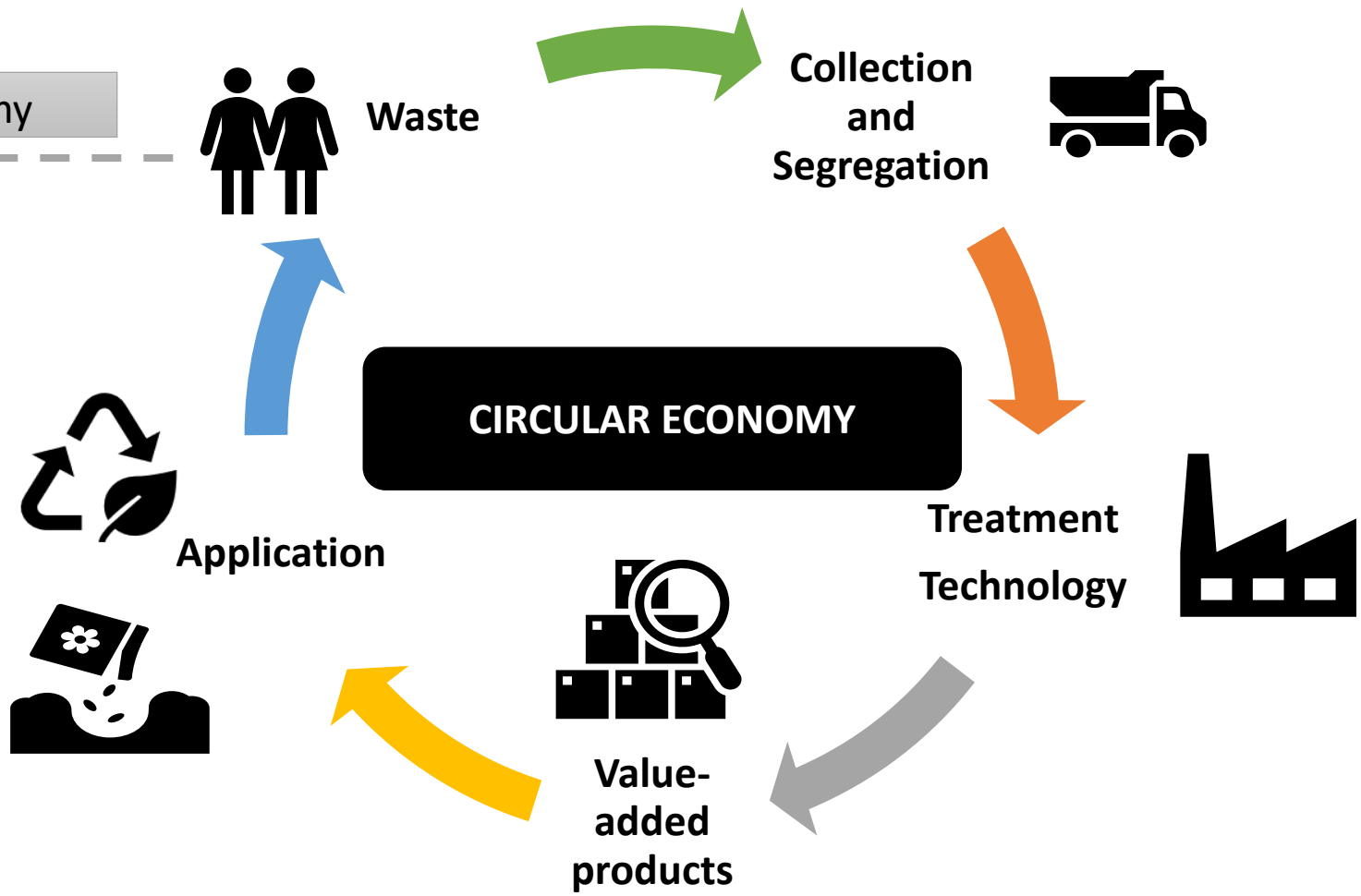
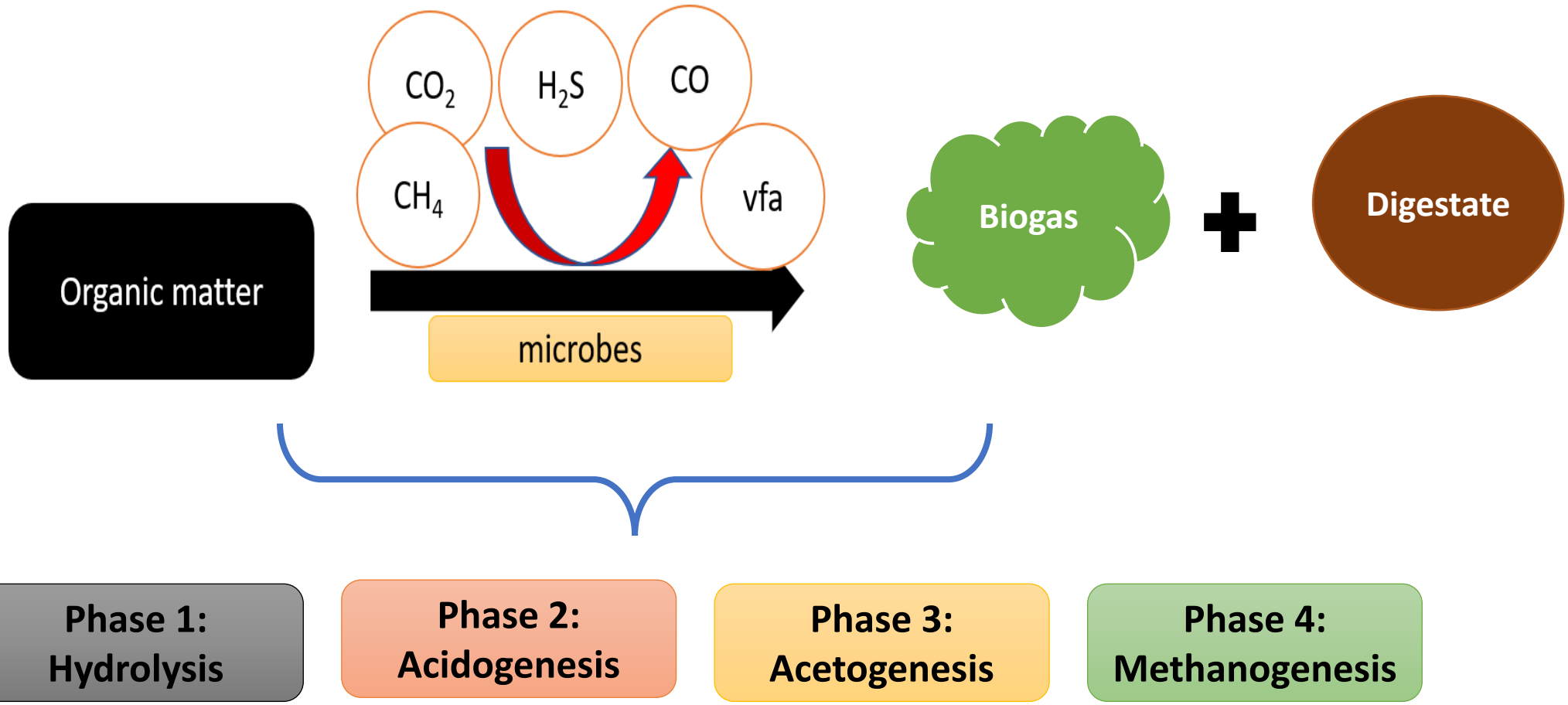
1.0 INTRODUCTION



Anaerobic Digestion (AD):



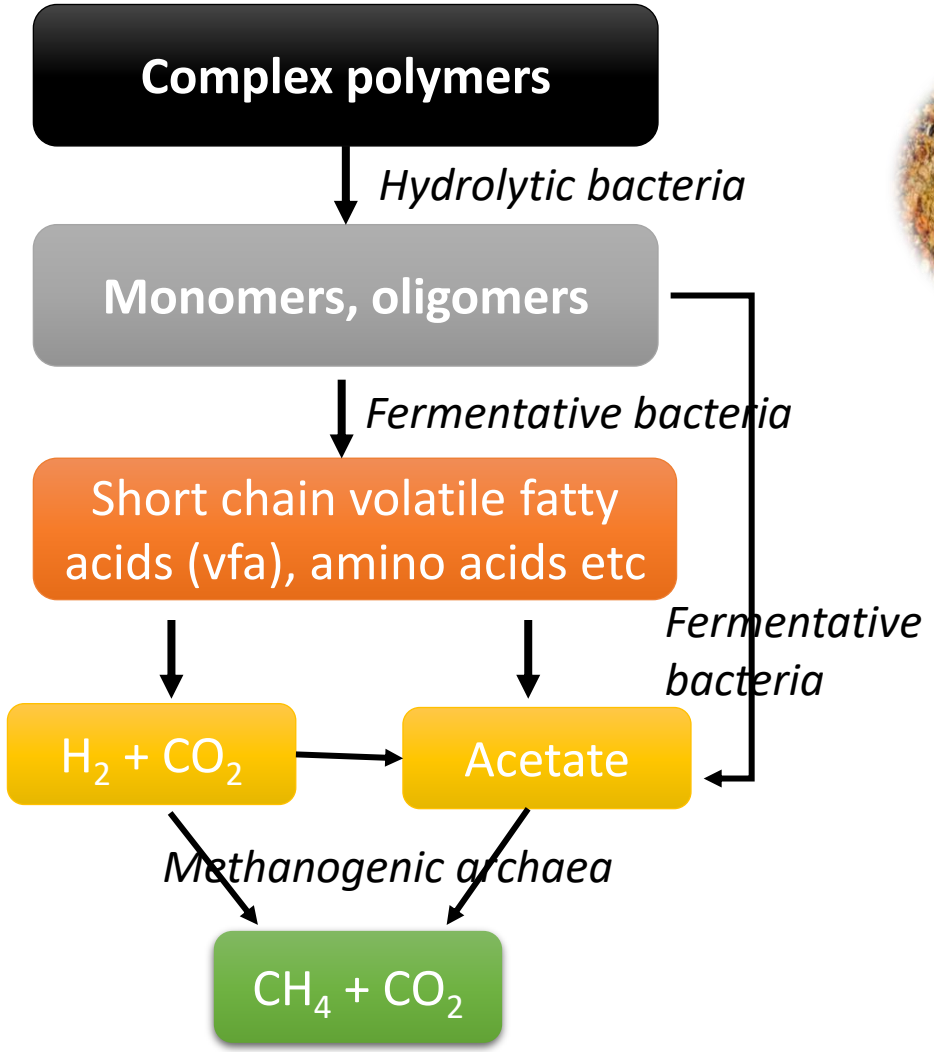
The State-of-the Art of AD:

Phase 1: Hydrolysis

Phase 2: Acidogenesis

Phase 3: Acetogenesis

Phase 4: Methanogenesis



Fast hydrolysis leading to **high acid** production and accumulation

Acidic environment **favours bacteria** (acid producers)

Low CH_4 yield due to acid and other inhibitors

Methanogens thrive at pH 6.5-7.2

Problem statements:

- The chemical composition of food waste of different origins can affect the potential biogas yield

- Batch test to determine the biogas potential is time consuming → requires reliable and rapid predictive model

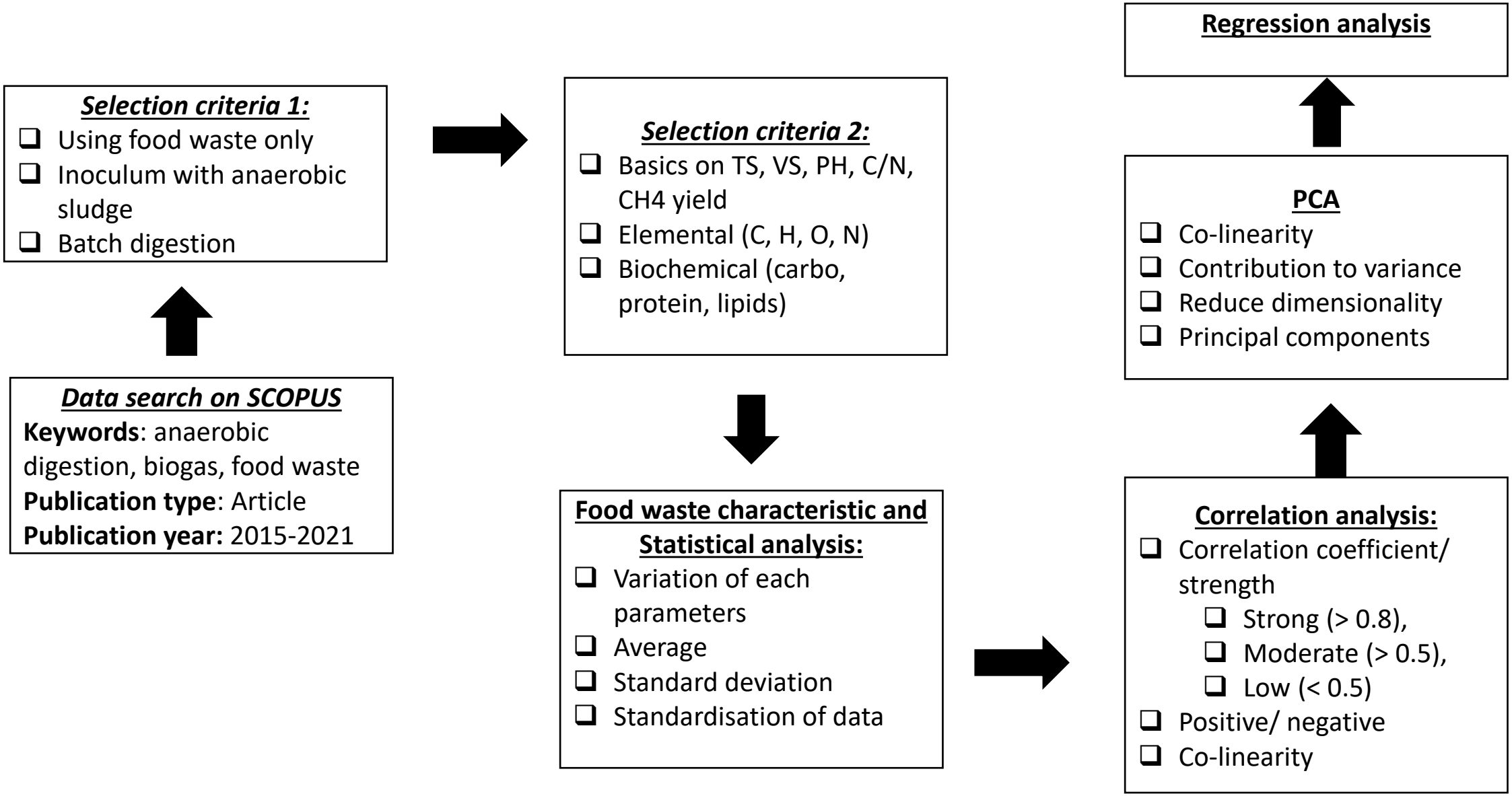
Objectives:

(1) To study the variation in the characteristic on FW of different origins

(2) To perform correlation and PCA analysis among FW characteristic with biogas yield

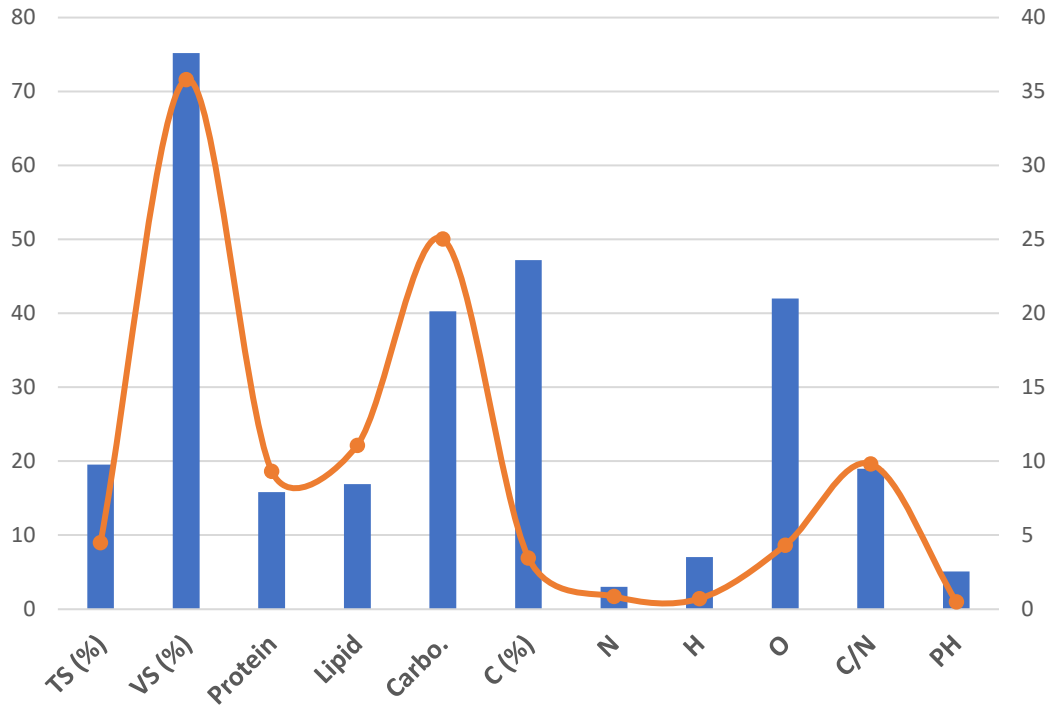
(3) To establish such relationships for better process design and modelling approaches

2.0 METHODOLOGY

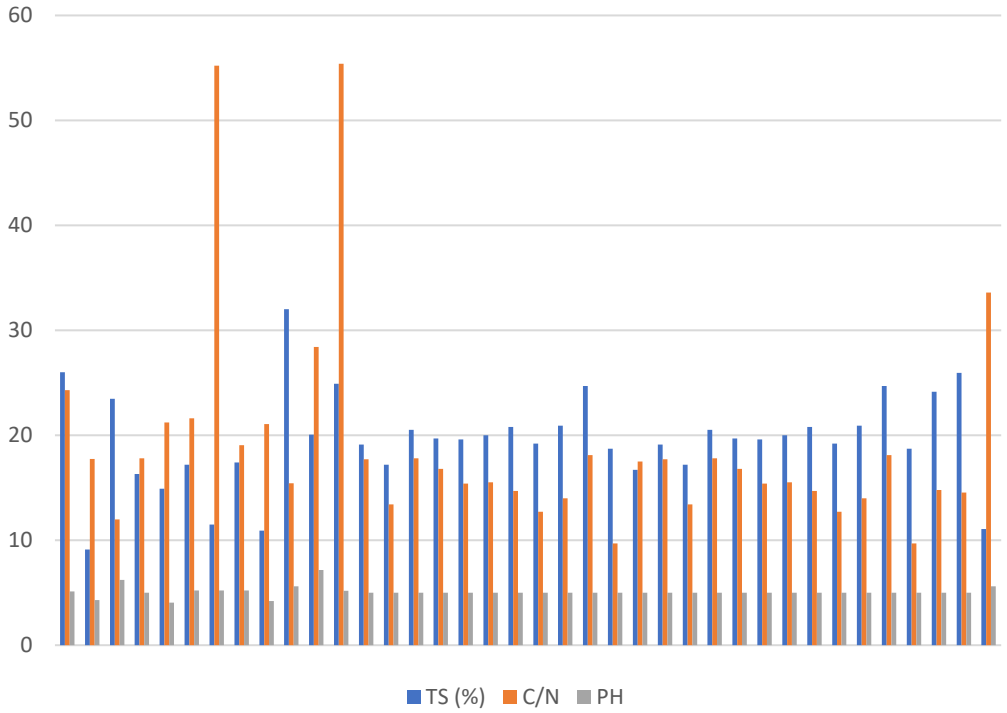


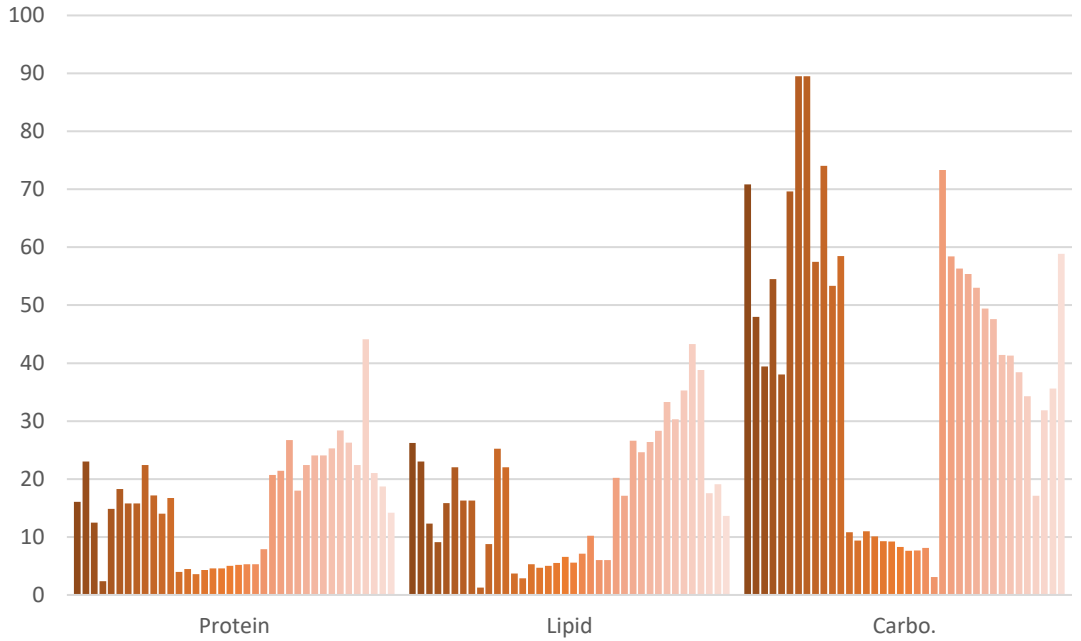
3.0 RESULTS & DISCUSSION

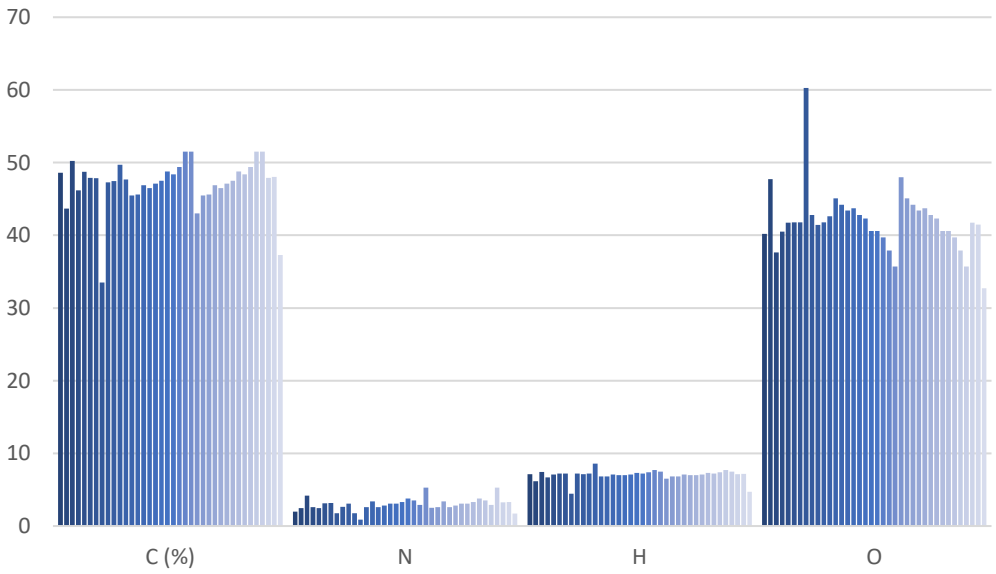
3.1 Food Waste Characteristics

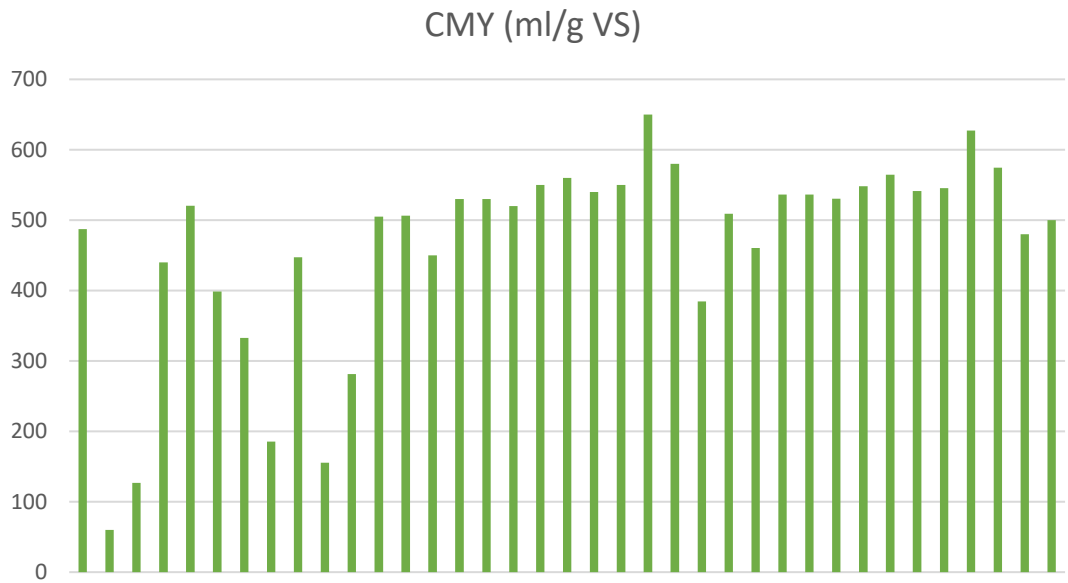


Characteristics	Value	Std.
TS (% dw)	19.5	4.49
VS (% dw)	75.18	35.79
Protein (%)	15.82	9.21
Lipid (%)	16.88	11.08
Carbo. (%)	40.25	25.01
C (%)	47.17	3.46
H (%)	2.99	0.85
N (%)	7.02	0.7
O (%)	42.0	4.31
C/N	18.98	9.8
PH	5.09	0.48
CH4 yield (ml/g VS)	457.2	147.45


60
50
40
30
20
10
0
TS (%)
C/N
PH


100
90
80
70
60
50
40
30
20
10
0
Protein
Lipid
Carbo.


70
60
50
40
30
20
10
0
C (%)
N
H
O


CMY (ml/g VS)
700
600
500
400
300
200
100
0

3.2 Correlation Analysis:

	TS (%)	VS (%)	Protein	Lipid	Carbo.	C (%)	N	H	O	C/N	PH	MY (ml/g V
TS (%)	1											
VS (%)	-0.627240966	1										
Protein	-0.034466336	-0.11132	1									
Lipid	0.263118614	-0.04049	0.85632606	1								
Carbo.	-0.133652524	-0.04861	0.66509153	0.523915	1							
C (%)	0.519076885	-0.05158	0.1260306	0.378142	-0.45194	1						
N	-0.158295602	-0.01844	0.28768099	0.162613	-0.35017	0.614512	1					
H	0.598663995	-0.03301	0.0745105	0.386736	-0.42427	0.980685	0.471492	1				
O	-0.403939495	0.04581	-0.17028651	-0.3569	0.460652	-0.98448	-0.74319	-0.9374	1			
C/N	0.275499818	0.072016	-0.27027401	-0.08344	0.282591	-0.41277	-0.94244	-0.26844	0.5602	1		
PH	0.030711925	-0.00762	-0.00865131	0.017494	-0.0414	0.044751	0.02165	0.043984	-0.04264	-0.01971	1	
CMY (ml/g VS)	0.501595894	0.205546	-0.03044462	0.341911	-0.41062	0.857965	0.266404	0.892897	-0.78638	-0.03791	0.054884	1

- **Two main categories →**
  - **(1) biochemical composition**
  - **(2) elemental composition**

Positive correlation among independent variables:

- Protein and lipid
- Protein and carbo
- Lipid and carbo
- TS and C
- TS and H
- C and N
- C and H
- O and C/N

Negative correlation among independent variables:

- TS and VS
- C and O
- H and O
- N and O
- C/N and N

Correlation with response variable:

- TS
- C
- H
- O

3.3 Principal Component Analysis

Eigen-analysis of the Correlation Matrix:

Eigenvalue	4.0012	2.1147	1.6177	1.2839	1.0209
Proportion	0.333	0.176	0.135	0.107	0.085
Cumulative	0.333	0.510	0.644	0.751	0.837

Variable	PC1	PC2	PC3	PC4	PC5
TS	0.236	0.138	-0.339	-0.111	-0.611
VS	0.291	-0.073	0.008	0.353	-0.277
Protein	-0.012	0.558	0.409	-0.039	-0.009
Lipid	0.058	0.604	0.190	0.021	-0.105
Carbo.	-0.340	0.392	-0.039	0.126	-0.072
C	0.443	0.156	-0.137	-0.028	0.185
N	0.326	-0.041	0.329	-0.393	0.108
H	0.405	0.168	-0.230	-0.223	0.087
O	-0.300	-0.130	0.171	0.261	-0.534
C/N	-0.192	0.204	-0.429	0.435	0.385
PH	-0.047	0.174	-0.519	-0.466	-0.186

3.4 Regression Analysis:

When all are used:

CMY (ml/g VS) = 105 + 4.12 TS (%) + 1.75 VS (%) + 1.38 Protein + 1.99 Lipid - 2.54 Carbo. + 24.5 C (%) - 48.9 N - 54 H + 2.32 O + 0.62 C/N- 108 PH [*R-Sq = 72.4% R-Sq(adj) = 60.8%]*

When only biochemical composition parameters are used:

CMY (ml/g VS) = 541 - 3.24 Protein + 5.19 Lipid - 1.52 Carbo.

[R-Sq = 71.2% R-Sq(adj) = 66.6%]

When only elemental composition parameters are used:

CMY (ml/g VS) = - 644 + 54.4 C (%) - 47.3 N - 178 H

[R-Sq = 91.8% R-Sq(adj) = 90.5%]

3.5 Limitations & Challenges:

- Does not account the operational parameters, such as loading rate, retention time, temperature, F/M loadings etc
- Potential vs soluble/accessible OM
- Methane yield due to acidification-induced lag phase or adaptation of microbes not included
- Missing data on some characteristics
- Only linear regression model is applied

4.0 Conclusion

- The food waste characteristic with the highest variation (in terms of std.) are VS, Protein, Lipid, Carbo., and C/N.

- With cumulative methane yield as response variable, the multivariate analysis showed that the predictor variables can be categorised into PC 1 (elemental composition), PC 2 (biochemical composition).

- Future work can be focusing on including more parameters that reflect intrinsically on the substrate available, e.g. soluble COD, organic loading rate, with the addition of non-linear modelling such as machine learning approch

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THANK YOU FOR YOUR KIND ATTENTION

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