PREPARATION AND CHARACTERIZATION OF COMPOST TEA DERIVED FROM ROCKWEED RESIDUES

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Non-aerated compost tea was prepared from compost based on rockweed (Ascophyllum nodosum) residue fermented in water. Electrical conductivity, pH, dry mater, ash, macronutrient, micronutrient, and contaminant contents of compost tea prepared under different fermentation conditions were determined. The effects of fermentation process factors, i.e., water/compost mass ratio (4.2–9.8 g/g) and fermentation time (4.2–9.8 days = 100–236 h), on the relevant physicochemical properties of compost tea were quantified using second-order polynomial models. Optimal levels of fermentation process factors (4.2 g/g and 7 days = 168 h) were identified based on desirability function approach. Non-aerated compost tea produced under optimal fermentation conditions will be tested for lettuce germination and seedling growth. Recycling rockweed residues using composting and compost fermentation could have relevant positive effects on the environment and plant growth, development, and/or health.

Keywords: compost fermentation, compost tea, modelling, optimization, rockweed (*Ascophyllum nodosum*)

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1. Introduction

Compost tea (CT) is an organic liquid obtained by fermenting compost under non-aerated or aerated conditions. There are two main techniques to produce non-aerated or aerated CT, *i.e.*: (i) the compost is put in a bag, the bag is placed in a vessel with water, fermentation occurs for a period of time (from a few hours to a few weeks), and then the bag is removed from the liquid phase (CT); (ii) compost and water are placed in a vessel, and the mixture is initially stirred vigorously; after fermentation, the slurry is filtrated (using a sieve or cheesecloth), obtaining CT as a filtrate [1–5].

Due to its composition, especially macronutrients, micronutrients, humic acids, phytohormones, and beneficial microorganisms, CT can significantly improve the soil quality, plant growth and/or development as well as reduce the incidence and severity of plant pests and diseases produced by pathogens [1–9]. Many studies in the related literature have reported positive effects of CT on the growth, development, and/or health of various seedlings and plants, *e.g.*, lettuce [10], pepper [11–13], tomato [14–16], potato [17–19]. Consequently, CT represents an eco-friendly alternative for sustainable agriculture focused on the reduction of synthetic fungicides and fertilizers [10–19].

The composition and efficacy of CT can be significantly affected by the type of compost and fermentation process conditions, *e.g.*, presence and duration of aeration, water/compost ratio, temperature, pH, duration, nutrient additives (including glucose, sucrose, molasses, humic materials, fish meal, whey, rock dust, plant or yeast extracts). Mature compost derived from green waste, prunings, manures, and bedding is commonly used to produce CT [2,3,11,17]. Generally, aerated CT is prepared using continuous or discontinuous aeration of slurry for 1–7 days, whereas non-aerated CT is produced without or with minimal aeration for 3–21 days [2–4]. The water/compost mass ratio for both aerated and non-aerated CT is usually in the range of 3–10 g/g [2,3,6–19]. Numerous studies have reported that various plant diseases, *e.g.*, grey mold, apple scab, leaf spots, damping-off, root rot, powdery and downy mildews, can be prevented/controlled using non-aerated CT [1–5,8,14]. Moreover, non-aerated CT can significantly improve seed germination as well as plant/seedling growth and development [1,2,6,14]. The efficacy of non-aerated CT depends on both biotic (beneficial microorganisms) and abiotic (inorganic nutrients and organic molecules) components [2,14].

Preparation of non-aerated CT from seaweed residue-based compost fermented in water, its characterization, and optimization of the fermentation factors, *i.e.*, water/compost mass ratio and fermentation time, are presented in this paper.

2. Materials and methods

Compost preparation

Rockweed (*Ascophyllum nodosum*) residues (50 L) resulting from the production of a liquid fertilizer were composted with LECA (lightweight expanded clay aggregate) (15 L) and granulated sugar (1.5 L) in a compost tumbler (Jora Composter JK 270) [20]. Images of the compost are shown in Fig. 1a.

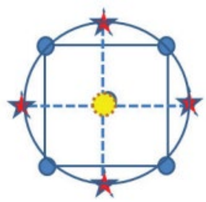
Compost tea preparation

The slurry consisting of compost and water was stirred once at the beginning of fermentation and then left in the dark at 25 °C. According to a Central Composite Design (CCD) [21], 12 experiments were performed at different levels of selected process factors, *i.e.*, liquid (water)/solid (compost) mass ratio (R_{LS} = 4.2–9.8 g/g) and fermentation time (t = 4.2–9.8 days = 100–236 h), which are specified in Table 1. Table 1 also contains the levels of dimensionless factors (x_1 and x_2) defined by Eqs. (1) and (2). At the end of each experiment, the broth was filtered through a 0.020 mm sieve and the filtrate (CT) was analyzed. Bottles with CT obtained by fermenting the compost under different operating conditions are shown in Fig. 1b.

Table 1

Levels of fermentation factors, minimum, maximum, mean, and star points in CCD

Experimental run	R_{LS} (g/g)	t (days)	x_1	x_2
1	5	5	-1	-1
2	5	9	-1	1
3	9	5	1	-1
4	9	9	1	1
5	7	7	0	0
6	7	7	0	0
7	4.2	7	-1.41	0
8	9.8	7	1.41	0
9	7	4.2	0	-1.41
10	7	9.8	0	1.41
11	7	7	0	0
12	7	7	0	0
MIN	5	5	-1	-1
MAX	9	9	1	1
m=(*MIN*+*MAX*)/2	7	7	0	0
M=(*MAX*–*MIN*)/2	2	2	1	1
LOW STAR POINT (m–1.41M)	4.2	4.2	-1.41	-1.41
HIGH STAR POINT (m+1.41M)	9.8	9.8	1.41	1.41



$$x_1 = \frac{R_{LS} - \frac{R_{LS,MAX} + R_{LS,MIN}}{2}}{\frac{R_{LS,MAX} - R_{LS,MIN}}{2}} = \frac{R_{LS} - 7}{2} \quad (1)$$

$$x_2 = \frac{t - \frac{t_{MAX} + t_{MIN}}{2}}{\frac{t_{MAX} - t_{MIN}}{2}} = \frac{t - 7}{2} \quad (2)$$

(a) (b)

Fig. 1. Compost obtained in the compost tumbler by composting rockweed (*A. nodosum*) residues with LECA (lightweight expanded clay aggregate) and granulated sugar (a) and related non-aerated compost tea (CT) (b).

Compost tea analysis

The following physicochemical parameters of non-aerated CT obtained at different levels of fermentation factors (Table 1) were determined: electrical conductivity (*EC*), pH (*pH*), dry matter content (*DM*), ash content (*Ash*), macronutrient, micronutrient, and contaminant contents (*C*, *N*, *P*, *K*, *Ca*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, *Mn*, and *Ni*). Analysis methods were detailed in our previous papers [22–24]. *EC* and *pH* were measured using a Metler Toledo SevenExcellence pH/Conductivity Meter S470. *DM* and *Ash* were determined using a Memmert UN110 oven and a Nabertherm B150 oven, respectively. *C* and *N* were measured using a EuroVector EA3100 Elemental Analyzer, and *P*, *K*, *Ca*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, *Mn*, and *Ni* using an Agilent 7700 ICP-MS. All measurements were performed in triplicate.

Data processing

The values of CT properties obtained at different levels of fermentation factors were processed using principal component analysis (PCA) [23–25]. The effects of fermentation factors on process responses were quantified using second-order polynomial models. The desirability function approach [21,25,26] was used to optimize the fermentation process factors. The Pearson correlation coefficient (*r*) was used to assess the strength of the linear correlations between different parameters. Statistical analysis, modelling, and process factor optimization were performed using XLSTAT version 2019.1.

3. Results and discussions

Compost tea characterization

Minimum values (*MIN*), maximum values (*MAX*), mean values (*m*), and standard deviations (*SD*) of CT properties (triplicate measurements) corresponding to 12 experimental runs (Table 1) are specified in Table 2. Tabulated data highlight a lower variability of *pH*, *C*, *N*, and *C/N* (coefficients of variation less than 7%) as well as a higher variability of *Ca*, *Cr*, *Cu*, *Fe*, *Mn*, and *Ni* (coefficients of variation higher than 40%).

Table 2

Indicators of position (minimum, maximum, and mean values) and variability (standard deviation) of selected variables of CT

Variable			Indicator			
Name	Symbol	Units	*MIN*	*MAX*	*m*	*SD*
Electrical conductivity	*EC*	dS/m	5.693	14.74	8.756	2.371
pH	*pH*	-	9.046	9.859	9.521	0.224
Dry matter content	*DM*	%	0.911	2.965	1.616	0.533
Ash content	*Ash*	%	0.463	1.949	0.932	0.350
Carbon content	*C*	%	21.54	24.14	23.14	0.729
Nitrogen content	*N*	%	0.964	1.247	1.090	0.069
C/N ratio	*C/N*	-	18.70	23.86	21.30	1.231
Phosphorus content	*P*	mg/kg	13.73	39.33	21.91	6.241
Potassium content	*K*	%	0.277	0.764	0.442	0.135
Calcium content*	*Ca*	mg/kg	76.61	407.9	142.5	72.60
Magnesium content	*Mg*	mg/kg	37.00	171.5	89.16	34.16
Sodium content	*Na*	mg/kg	447.1	1484	798.5	247.8
Chromium content	*Cr*	mg/kg	0.075	1.096	0.397	0.259
Copper content	*Cu*	mg/kg	0.110	0.940	0.232	0.137
Iron content	*Fe*	mg/kg	14.53	98.78	41.51	20.45
Manganese content**	*Mn*	mg/kg	0.099	0.826	0.362	0.182
Nickel content	*Ni*	mg/kg	0.189	1.178	0.496	0.216

* only for CT7–CT12; ** only for CT1, CT2, and CT5–CT12.

Results of PCA

A data matrix with 36 rows (number of triplicate samples corresponding to experimental runs 1, 2…12 in Table 1, *i.e.*, CT1, CT2…CT12) and 14 columns (number of variables, including *EC*, *pH*, *DM*, *Ash*, *C*, *N*, *P*, *K*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni*) was used in PCA. The eigenvalues corresponding to the first two principal components (PCs), *i.e.*, 9.86 for PC1 and 1.52 for PC2, were >1 and they explained 81.28% (70.44% + 10.84%) of the total variance. Data presented in

Figure 2 (PCA bi-plot), Table 3 (factor loadings), and Table 4 (correlation matrix) reveal the following aspects:

- depending on significant levels of factor loadings (highlighted in bold in Table 3), the most important variables are *EC*, *pH*, *DM*, *Ash*, *P*, *K*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni* for PC1 as well as *C* and *N* for PC2;

- CT obtained in the experimental run 7 (CT7) has higher values of *EC*, *DM*, *Ash*, *P*, *K*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni*, but lower values of *pH* than the other samples [discrimination on PC1 between CT7 and the other samples (blue ellipses in Fig. 2)];

- *EC, DM*, *Ash*, *C*, *N*, *P*, *K*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni* are directly correlated, and they are inversely correlated with *pH* (Table 4); except for the correlation coefficients (r) between *N* and each of *EC*, *DM*, *K*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni* ($0.01 \le r \le 0.33$), *C* and each of *EC*, *K*, *Cu*, and *Ni* ($0.11 \le r \le 0.30$), the other r are significant ($\alpha = 0.05$).

Table 3

Factor loadings

No.	Name	Symbol	PC1	PC2
1	Electrical conductivity	*EC*	**0.94**	-0.19
2	pH	*pH*	**-0.75**	-0.44
3	Dry matter content	*DM*	**0.96**	-0.11
4	Ash content	*Ash*	**0.98**	-0.05
5	Carbon content	*C*	0.48	**0.74**
6	Nitrogen content	*N*	0.35	**0.62**
7	Phosphorus content	*P*	**0.96**	-0.08
8	Potassium content	*K*	**0.90**	-0.25
9	Magnesium content	*Mg*	**0.90**	0.26
10	Sodium content	*Na*	**0.98**	-0.10
11	Chromium content	*Cr*	**0.82**	0.04
12	Copper content	*Cu*	**0.81**	-0.25
13	Iron content	*Fe*	**0.98**	0.00
14	Nickel content	*Ni*	**0.62**	-0.37

Significant values are highlighted in bold.

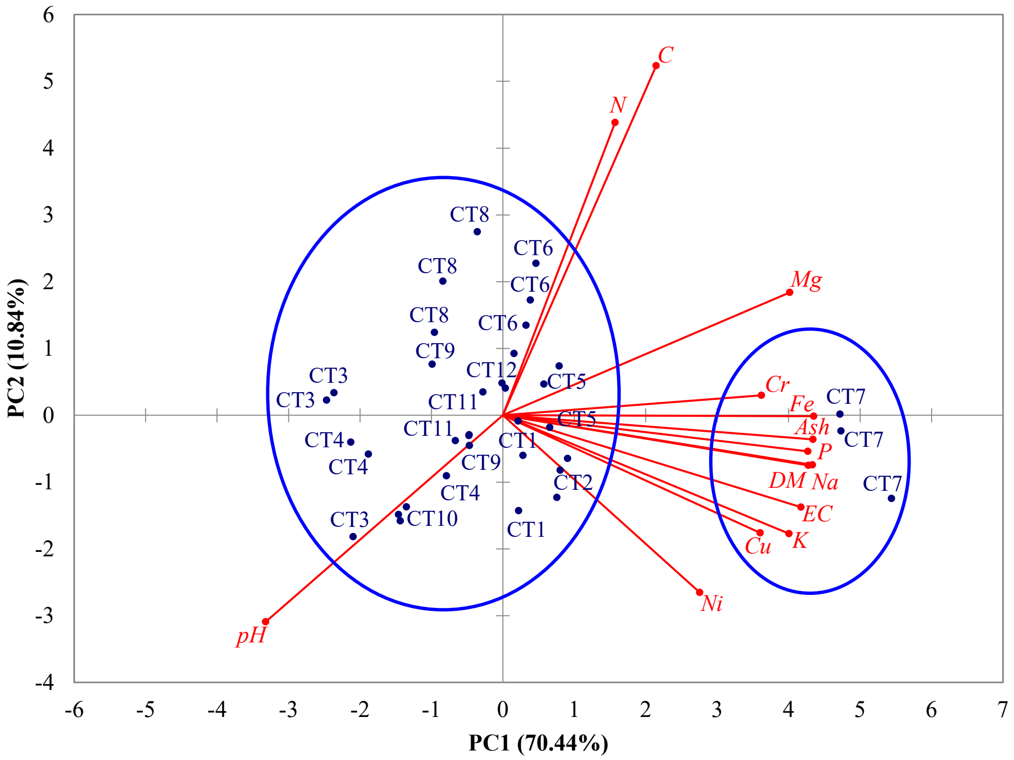


Fig. 2. Projections of variables (*EC*, *pH*, *DM*, *Ash*, *C*, *N*, *P*, *K*, *Mg*, *Na*, *Cr*, *Cu*, *Fe*, and *Ni*) and samples (CT1, CT2…CT12) on the factor-plane PC1–PC2.

Table 4

Correlation matrix

Var	*EC*	*pH*	*DM*	*Ash*	*C*	*N*	*P*	*K*	*Mg*	*Na*	*Cr*	*Cu*	*Fe*	*Ni*
EC	**1**													
pH	**-0.58**	**1**												
DM	**0.99**	**-0.64**	**1**											
Ash	**0.97**	**-0.68**	**0.98**	**1**										
C	0.30	**-0.64**	**0.39**	**0.45**	**1**									
N	0.29	**-0.41**	0.33	**0.34**	**0.43**	**1**								
P	**0.93**	**-0.67**	**0.94**	**0.93**	**0.37**	**0.33**	**1**							
K	**0.98**	**-0.49**	**0.96**	**0.93**	0.24	0.28	**0.90**	**1**						
Mg	**0.74**	**-0.77**	**0.80**	**0.85**	**0.68**	**0.33**	**0.83**	**0.70**	**1**					
Na	**0.95**	**-0.65**	**0.96**	**0.96**	**0.38**	0.29	**0.98**	**0.93**	**0.86**	**1**				
Cr	**0.64**	**-0.69**	**0.67**	**0.72**	**0.37**	0.18	**0.78**	**0.57**	**0.84**	**0.78**	**1**			
Cu	**0.75**	**-0.51**	**0.75**	**0.79**	0.23	0.12	**0.77**	**0.73**	**0.68**	**0.79**	**0.69**	**1**		
Fe	**0.89**	**-0.74**	**0.92**	**0.94**	**0.45**	0.32	**0.93**	**0.86**	**0.92**	**0.95**	**0.87**	**0.78**	**1**	
Ni	**0.58**	**-0.37**	**0.58**	**0.59**	0.11	0.01	**0.56**	**0.57**	**0.46**	**0.57**	**0.52**	**0.54**	**0.62**	**1**

Var – variable; values in bold of correlation coefficient (r) are different from 0 with a significance level $\alpha = 0.05$.

Prediction of process responses

Statistical models described by Eq. (3) link the predicted process responses ($y_{j,pr}$, j = 1, 2…14), *i.e.*, EC_{pr}, pH_{pr}, DM_{pr}, Ash_{pr}, C_{pr}, N_{pr}, P_{pr}, K_{pr}, Mg_{pr}, Na_{pr}, Cr_{pr}, Cu_{pr}, Fe_{pr}, and Ni_{pr}, to x_1, x_1^2, x_2, x_2^2, and x_1x_2.

$$y_{j,pr} = \alpha_{0j} + \alpha_{1j}x_1 + \alpha_{11j}x_1^2 + \alpha_{2j}x_2 + \alpha_{22j}x_2^2 + \alpha_{12j}x_1x_2 \text{ , } j = 1, 2\ldots14 \qquad (3)$$

Regression coefficients in Eq. (3), *i.e.*, a_{0j}, a_{1j}, a_{11j}, a_{2j}, a_{22j}, and a_{12j}, were identified from mean (m) experimental values of process responses (corresponding to triplicate measurements) specified in Table 5. The values of regression coefficients, determination coefficient (R^2), F statistic (F), and significance F (p-value for F), which are summarized in Table 5, indicate the following:

(i) pH_{pr}, N_{pr}, Cr_{pr}, and Ni_{pr} do not vary significantly with x_1, x_1^2, x_2, x_2^2, or x_1x_2 ($0.163 \le R^2 \le 0.679$, $0.235 \le F \le 2.533$, and $0.144 \le p \le 0.933$);

Table 5

Mean experimental values of process responses (corresponding to triplicate measurements) and values of regression coefficients, determination coefficient, *F* statistic, and significance *F* (*p*-value for *F*) at different levels of dimensionless fermentation factors

Run	x_1	x_2	EC_m (dS/m)	pH_m	DM_m (%)	Ash_m (%)	C_m (%)	N_m (%)	P_m (mg/kg)	K_m (%)
j			1	2	3	4	5	6	7	8
1	-1	-1	10.27	9.554	1.831	1.032	23.06	1.050	23.39	0.548
2	-1	1	11.28	9.610	2.186	1.214	22.77	1.133	23.52	0.619
3	1	-1	5.727	9.675	0.918	0.477	22.73	1.033	13.86	0.282
4	1	1	6.696	9.855	1.118	0.617	22.48	1.087	14.90	0.320
5	0	0	9.168	9.332	1.780	1.004	23.34	1.084	24.21	0.447
6	0	0	8.948	9.307	1.714	0.993	24.10	1.177	24.12	0.435
7	-1.41	0	14.65	9.052	2.949	1.858	23.79	1.138	38.50	0.750
8	1.41	0	6.421	9.264	1.201	0.728	23.84	1.124	16.29	0.310
9	0	-1.41	7.811	9.614	1.394	0.751	22.63	1.117	22.77	0.384
10	0	1.41	7.497	9.683	1.217	0.664	21.55	1.028	17.85	0.357
11	0	0	8.081	9.653	1.520	0.865	23.47	1.017	20.57	0.399
12	0	0	8.511	9.656	1.562	0.979	23.88	1.088	20.61	0.415
a_{0j}			**8.677**	**9.487**	**1.644**	**0.960**	**23.69**	**1.092**	**22.38**	**0.424**
a_{1j}			**-2.597**	0.084	**-0.557**	**-0.344**	-0.069	-0.010	**-6.195**	**-0.149**
a_{11j}			**0.780**	-0.097	0.171	0.125	0.013	0.013	1.275	**0.051**
a_{2j}			0.192	0.042	0.038	0.025	-0.257	0.001	-0.723	0.009
a_{22j}			-0.662	0.148	**-0.213**	**-0.168**	**-0.850**	-0.016	-2.268	**-0.029**
a_{12j}			-0.011	0.031	-0.038	-0.010	0.009	-0.007	0.228	-0.008
R_j^2			0.955	0.551	0.934	0.918	0.896	0.163	0.799	0.978
F_j			25.55	1.472	16.93	13.39	10.33	0.235	4.765	53.14
p_j			0.001	0.323	0.002	0.003	0.007	0.933	0.042	0.000

Table 5 (continued)

Run	x_1	x_2	Mg_m (mg/kg)	Na_m (mg/kg)	Cr_m (mg/kg)	Cu_m (mg/kg)	Fe_m (mg/kg)	Ni_m (mg/kg)
j			9	10	11	12	13	14
1	-1	-1	78.78	883.2	0.270	0.254	39.12	1.193
2	-1	1	85.52	887.9	0.213	0.262	49.27	1.366
3	1	-1	37.46	453.0	0.111	0.112	14.54	0.620
4	1	1	43.08	551.2	0.104	0.141	17.79	0.779
5	0	0	101.4	860.6	0.622	0.225	52.94	1.097
6	0	0	97.74	845.1	0.315	0.194	41.81	1.092
7	-1.41	0	170.4	1465	1.039	0.569	96.62	1.939
8	1.41	0	103.7	600.1	0.402	0.161	36.60	0.764
9	0	-1.41	70.91	723.8	0.407	0.208	30.11	0.981
10	0	1.41	56.19	657.5	0.353	0.196	29.74	0.935
11	0	0	100.4	771.1	0.332	0.218	38.89	1.007
12	0	0	108.9	800.5	0.505	0.214	42.80	1.056
a_{0j}			**102.1**	**819.3**	**0.443**	**0.213**	**44.11**	**0.448**
a_{1j}			**-22.26**	**-248.8**	-0.146	**-0.105**	**-17.62**	-0.107
a_{11j}			7.716	64.69	0.045	0.053	6.729	0.108
a_{2j}			-1.059	1.149	-0.018	0.002	1.611	0.013
a_{22j}			**-29.05**	-106.3	-0.126	-0.028	-11.61	-0.037
a_{12j}			-0.282	23.37	0.012	0.005	-1.725	-0.074
R_j^2			0.764	0.870	0.437	0.795	0.814	0.679
F_j			3.878	8.049	0.930	4.654	5.265	2.533
p_j			0.065	0.012	0.522	0.044	0.034	0.144

Statistically significant regression coefficients are highlighted in bold.

(ii) EC_{pr}, DM_{pr}, Ash_{pr}, C_{pr}, P_{pr}, K_{pr}, Na_{pr}, Cu_{pr}, and Fe_{pr} vary significantly with at least one of x_1, x_1^2, x_2, x_2^2, and x_1x_2, and there is a good agreement between experimental and predicted values of process responses ($0.795 \leq R^2 \leq 0.978$, $4.654 \leq F \leq 53.14$, and $0.0001 \leq p \leq 0.044$); EC_{pr} increases significantly with an increase in x_1^2 and a decrease in x_1; DM_{pr} and Ash_{pr} increase significantly with a decrease in x_1 and x_2^2; C_{pr} increases significantly with a decrease in x_2^2; K_{pr} increases significantly with an increase in x_1^2 and a decrease in x_1 and x_2^2; P_{pr}, Na_{pr}, Cu_{pr}, and Fe_{pr} increase significantly with a decrease in x_1;

(iii) Mg_{pr} increases significantly with a decrease in x_1 and x_2^2, but the statistical model defined by Eq. (3) for $j = 9$ is statistically non-significant ($F = 3.878$ and $p = 0.065$).

Optimization of fermentation process conditions

Optimization of fermentation process factors, aiming at maximizing the process responses in terms of EC_{pr}, DM_{pr}, Ash_{pr}, C_{pr}, P_{pr}, K_{pr}, Na_{pr}, Cu_{pr}, and Fe_{pr} was based on the desirability function approach. The optimal levels of process factors were $x_{1,opt} = -1.41$ ($R_{LS,opt} = 4.2$ g/g) and $x_{2,opt} = 0$ ($t_{opt} = 7$ days). The values of the process responses predicted by Eq. (3) at these optimal factor levels ($y_{j,pr,opt}$)

and corresponding mean experimental values ($y_{j,m,opt}$) are summarized in Table 6. Under these optimal conditions, the value of desirability function was 0.87. The values of percentage prediction error (Table 6), *i.e.*, $\varepsilon = 100(y_{j,m,opt} - y_{j,pr,opt})/y_{j,m,opt}$, generally highlight a good or a reasonable agreement between the experimental and predicted optimal values. Non-aerated CT produced at optimal levels of process factors will be tested for lettuce germination and seedling growth.

Table 6

Experimental (mean of triplicate measurements) and predicted values of fermentation responses under optimal process conditions

j	Variable			Optimal values		
				Experimental	Predicted	Percentage prediction error
	Name	Symbol	Units	$y_{j,m,opt}$	$y_{j,pr,opt}$	ε (%)
1	Electrical conductivity	*EC*	dS/m	14.65	13.91	5.1
2	pH	*pH*	-	9.052	9.175	-1.4
3	Dry matter content	*DM*	%	2.949	2.774	5.9
4	Ash content	*Ash*	%	1.858	1.697	8.7
5	Carbon content	*C*	%	23.79	23.82	-0.1
6	Nitrogen content	*N*	%	1.138	1.133	0.4
7	Phosphorus content	*P*	mg/kg	38.50	33.69	12.5
8	Potassium content	*K*	%	0.750	0.736	1.9
9	Magnesium content	*Mg*	mg/kg	170.4	149.0	12.6
10	Sodium content	*Na*	mg/kg	1465	1301	11.2
11	Chromium content	*Cr*	mg/kg	1.039	0.739	28.9
12	Copper content	*Cu*	mg/kg	0.569	0.468	17.8
13	Iron content	*Fe*	mg/kg	96.62	82.49	14.6
14	Nickel content	*Ni*	mg/kg	0.967	0.815	15.7

4. Conclusions

Non-aerated compost tea (CT) was prepared from compost derived from rockweed residues. Water/compost mass ratio (R_{LS} = 4.2–9.8 g/g) and fermentation time (t = 4.2–9.8 days) were selected as process factors. CT obtained at R_{LS} = 4.2 g/g and t = 7 days had higher values of contents of electrical conductivity, dry matter, ash, P, K, Mg, Na, Cr, Cu, Fe, and Ni, but lower values of pH than the other samples.

Effects of fermentation factors on relevant process responses were quantified using second-order polynomial models. There was a good or a reasonable agreement between the experimental and predicted data. Optimization of fermentation factors, based on the desirability function approach, resulted in the following optimal levels of process factors: $R_{LS,opt}$ = 4.2 g/g and t_{opt} = 7 days.

The results obtained in this study could be used to optimize the compost fermentation process to produce non-aerated CT and to predict the process performances. CT produced at optimal levels of process factors will be tested for lettuce germination and seedling growth. Recycling rockweed residues using composting and compost fermentation could have significant agronomic environmental and agronomic benefits.

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REFERENCES

[1] *A.M. Litterick, L. Harrier, P. Wallace, C.A. Watson, M. Wood*, The role of uncomposted materials, composts, manures, and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production–A review, Crit. Rev. Plant Sci., **vol. 23**, no. 6, 2004, pp. 453-479.

[2] *N. Pilla, V. Tranchida-Lombardo, P. Gabrielli, A. Aguzzi, M. Caputo, M. Lucarini, A. Durazzo, M. Zaccardelli*, Effect of compost tea in horticulture, Horticulturae, **vol. 9**, no. 9, 2023, 984.

[3] *S. Scheuerell, W. Mahaffee*, Compost tea: Principles and prospects for plant disease control, Compost Sci. Util., **vol. 10**, no. 4, 2002, pp. 313-338.

[4] *S.J. Scheuerell, W.F. Mahaffee*, Variability associated with suppression of gray mold (*Botrytis cinerea*) on geranium by foliar applications of nonaerated and aerated compost teas, Plant Dis., **vol. 90**, no. 9, 2006, pp. 1201-1208.

[5] *C.C.G. St. Martin, R.A.I. Brathwaite*, Compost and compost tea: Principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production, Biol. Agric. Hortic., **vol. 28**, no. 1, 2012, pp. 1-33.

[6] *R. Jarboui, B. Dhouib, E. Ammar*, Effect of food waste compost (FWC) and its non-aerated fermented extract (NFCE) on seeds germination and plant growth, Open J. Soil Sci., **vol. 11**, no. 02, 2021, pp. 122-138.

[7] *H.A. Meshref, M.H. Rabie, A.M. El-Ghamry, M.A. El-Agamy*, Maximizing utilization of compost addition using foliar compost extract and humic substances in alluvial soil, Journal of Soil Sciences and Agricultural Engineering (JSSAE), **vol. 1**, no. 9, 2010, pp. 957-971.

[8] *H.C. Weltzien*, Some effects of composted organic materials on plant health, Agric. Ecosyst. Environ., **vol. 27**, no. 1-4, 1989, pp. 439-446.

[9] *D.B. Xu, Q.J. Wang, Y.C. Wu, G.H. Yu, Q.R. Shen, Q.W. Huang*, Humic-like substances from different compost extracts could significantly promote cucumber growth, Pedosphere, **vol. 22**, no. 6, 2012, pp. 815-824.

[10] *C. Pane, A.M. Palese, G. Celano, M. Zaccardelli*, Effects of compost tea treatments on productivity of lettuce and kohlrabi systems under organic cropping management, Ital. J. Agron., **vol. 9**, no. 3, 2014, pp. 153-156.

[11] *A.I. González-Hernández, M.B. Suárez-Fernández, R. Pérez-Sánchez, M.Á. Gómez-Sánchez, M.R. Morales-Corts*, Compost tea induces growth and resistance against *Rhizoctonia solani* and *Phytophthora capsici* in pepper, Agronomy, **vol. 11**, no. 4, 2021, 11, 781.

[12] *F. Marín, F. Diánez, M. Santos, F. Carretero, F.J. Gea, C. Castañeda, M.J. Navarro, J.A. Yau*, Control of *Phytophthora capsici* and *Phytophthora parasitica* on pepper (*Capsicum annuum* L.) with compost teas from different sources, and their effects on plant growth promotion, Phytopathol. Mediterr., **vol. 53**, 2014, pp. 216-228.

[13] *M. Zaccardelli, C. Pane, D. Villecco, A.M. Palese, G. Celano*, Compost tea spraying increases yield performance of pepper (*Capsicum annuum* L.) grown in greenhouse under organic farming system, Ital. J. Agron., **vol. 13**, 2018, pp. 229-234.

[14] *A. Dionne, R.J. Tweddell, H. Antoun, T.J. Avis*, Effect of non-aerated compost teas on damping-off pathogens of tomato, Can. J. Plant Pathol., **vol. 34**, no. 1, 2012, pp. 51-57.

[15] *M.R. Morales-Corts, R. Pérez-Sánchez, M.Á. Gómez-Sánchez*, Efficiency of garden waste compost teas on tomato growth and its suppressiveness against soilborne pathogens, Sci. Agric., **vol. 75**, 2018, pp. 400-409.

[16] *C. Pane, A.M. Palese, R. Spaccini, A. Piccolo, G. Celano, M. Zaccardelli*, Enhancing sustainability of a processing tomato cultivation system by using bioactive compost teas, Sci. Hortic., **vol. 202**, 2016, pp. 117-124.

[17] *A.I. González-Hernández, R. Pérez-Sánchez, J. Plaza, M.R. Morales-Corts*, Compost tea as a sustainable alternative to promote plant growth and resistance against *Rhizoctonia solani* in potato plants, Sci. Hortic., **vol. 300**, 2022, 111090.

[18] *J.J. López-Martín, M.R. Morales-Corts, R. Pérez-Sánchez, M.A. Gómez-Sánchez*, Efficiency of garden waste compost teas on potato growth and its suppressiveness against *Rhizoctonia*, Agric. For., **vol. 64**, 2018, pp. 7-14.

[19] *M. Samet, M. Charfeddine, L. Kamoun, O. Nouri-Ellouze, R. Gargouri-Bouzid*, Effect of compost tea containing phosphogypsum on potato plant growth and protection against *Fusarium solani* infection, Environ. Sci. Pollut. Res., **vol. 25**, 2018, pp. 18921-18937.

[20] *J. Cabell, A.-K. Løes*, Blue biomass composting technology, NORSØK Report, **vol. 8**, no. 4, 2023, pp. 1-50.

[21] *A.D. Dima, O.C. Pârvulescu, C. Mateescu, T. Dobre*, Optimization of substrate composition in anaerobic co-digestion of agricultural waste using central composite design, Biomass Bioenerg, 2020, **vol. 138**, 105602.

[22] *S.I. Calcan, O.C. Pârvulescu, V.A. Ion, C.E. Răducanu, L. Bădulescu, T. Dobre, D. Egri, A. Moț, V. Popa, M.E. Crăciun,* Valorization of vine prunings by slow pyrolysis in a fixed-bed reactor, Processes, 2022, **vol. 10**, no. 1, 37.

[23] *S.I. Calcan, O.C. Pârvulescu, V.A. Ion, C.E. Răducanu, L. Bădulescu, R. Madjar, T. Dobre, D. Egri, M. Andrei, L.M. Iliescu, et al.,* Effects of biochar on soil properties and tomato growth, Agronomy, 2022, **vol. 12**, no. 8, 1824.

[24] *D. Egri, O.C. Pârvulescu, V.A. Ion, C.E. Răducanu, S.I Calcan, L. Bădulescu, R. Madjar, C. Orbeci, T. Dobre, A. Mot, et al.,* Vine pruning-derived biochar for agronomic benefits. Agronomy 2022, **vol. 12**, no. 11, 2730.

[25] *A.M. Drăghici-Popa, A.C. Boscornea, A.M. Brezoiu, Ş.T. Tomas, O.C. Pârvulescu, R. Stan,* Effects of extraction process factors on the composition and antioxidant activity of blackthorn (*Prunus spinosa* L.) fruit extracts. Antioxidants, 2023, **vol. 12**, no. 10, 1897.

[26] *A.I. Gavrilă, A. Vartolomei, I. Călinescu, M. Vînătoru, O.C. Pârvulescu, G. Psenovschi, G., P. Chipurici, A. Trifan*, Ultrasound-assisted alkaline pretreatment of biomass to enhance the extraction yield of valuable chemicals. Agronomy, 2024, **vol. 14**, no. 5, 903.