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Influence of Varied Organic Carbon Sources on Cow Dung Compost Quality: A Comprehensive Meta-Analysis

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ABSTRACT

In the context of Indonesian agriculture, governmental endorsement of compost fertilization has been established as a strategy to mitigate agricultural waste and enhance soil properties. The integration of cow dung with organic carbon derived from agricultural residues is postulated to yield compost of a quality that conforms to the Indonesian National Standard (SNI). The objective of this meta-analysis was to ascertain the optimal organic carbon sources for the composting of cow dung by synthesizing data from 30 pertinent studies. The Hedges' effect size was computed utilizing Microsoft Excel 2016, while ANOVA, performed in SPSS version 22, facilitated the assessment of standard error means (SEMs) and the determination of statistical significance (p-values). It was observed that the organic carbon source exerted a significant influence on the compost's pH and nitrogen content, with an alkaline pH correlating with augmented nitrogen levels. The meta-analysis delineated variance in requisite composting durations when cow dung was amalgamated with distinct organic carbon materials, namely rice straw, weeds, vegetable/fruit remnants, rice husks, sawdust, palm oil by-products, and corn stalks. This variance was manifest across a spectrum from short-term to extended composting periods. The discernible impact of organic carbon materials on compost pH and nitrogen content underscores the necessity of strategic selection of these materials to optimize compost quality. By identifying the most efficacious organic carbon sources for cow dung composting, the study's insights can be instrumental in formulating guidelines that not only ensure compliance with SNI standards but also contribute to soil quality amelioration and the reduction of agricultural waste in Indonesia.

1. INTRODUCTION

The Republic of Indonesia has demonstrated a commitment to sustainable agricultural practices, notably through the President's endorsement and the Minister of Agriculture, Syahrul Yasin Limpo's advocacy for a transition towards organic and compost fertilizers [1]. This policy shift is timely, considering the mounting challenges surrounding the use of chemical fertilizers, including limited allocations and escalating prices. Amidst global uncertainties, with Russia and Ukraine, significant producers of raw materials for chemical fertilizers, embroiled in conflict, the Ministry of Agriculture advocates for a massive and independent adoption of organic and compost fertilizers by farmers. While not advocating complete abandonment of inorganic fertilizers, the ministry emphasizes balanced fertilization practices to enhance agricultural sustainability [2].

Cow dung compost, constituted by the decomposition of cow dung in conjunction with organic carbon sources such as dry leaves and straw, is posited as a sustainable alternative to chemical fertilizers. This integration not only diminishes reliance on inorganic options, but also holds potential for soil quality improvement. Nevertheless, the varied impact of different organic carbon materials on compost quality and nutritional content necessitates a thorough investigation, which has been enabled by recent technological and research advancements.

Diverse organic carbon materials, including straw, dry leaves, rice husks, and other agricultural residues, are utilized in cow dung compost production. These materials vary in characteristics and nutritional content, thereby influencing the resultant compost's quality [3]. The objective of this meta-analysis is to provide clear, objective insights into the effects of varying organic carbon materials on the quality of cow dung compost, thereby aiding farmers and organic fertilizer producers in selecting appropriate materials for compost production.

The composting process itself is dynamic, with constant fluctuations in temperature, pH, and nutrient availability affecting the composition and activity of microbial populations. Decomposition transpires in three phases: the mesophilic phase, which initiates the process, lasts for up to

10 days and involves rapid metabolism of sugars and simple carbohydrates at temperatures of 15-45°C; the thermophilic phase, lasting approximately two weeks, during which temperatures rise to 50-75°C, facilitating the destruction of many plant and human pathogens and the breakdown of complex biomolecules; and finally, the cooling and maturation phase, characterized by a decrease in microbial activity and an increase in the diversity of both microorganisms and metabolic products, leading to the degradation of complex natural polymers and the conversion of recalcitrant compounds into humus [4].

Several factors are known to influence the composting process, including the C/N ratio, aeration, particle size, porosity-structure-texture, temperature, pH, nutrient content, hazardous substance levels, composting duration, and humidity [5]. Optimal composting conditions have been identified: a C/N ratio of approximately 25-35:1, humidity levels of 45-62%, oxygen concentrations above 10%, a bulk density of 1000 lbs/cu yd, a pH between 6.5-8.0, and temperatures of 54-60°C [6]. The addition of various organic matter sources can alter the ideal C/N ratio, with the composition of lignin and cellulose in the organic substrate material affecting the composting process's efficiency and final compost quality.

The study at hand aims to conduct a comprehensive meta-analysis, synthesizing outcomes from 30 studies to determine the effects of various organic carbon materials on cow dung composting. The term 'meta-analysis' refers to a statistical approach that amalgamates results from multiple independent studies to form overarching conclusions. In this case, the meta-analysis is utilized to consolidate findings on the impact of different organic carbon materials in the composting process [7, 8]. The research examines materials such as straw, dry leaves, rice husks, and other agricultural wastes, each with unique characteristics and nutritional profiles. The anticipated outcome is to offer clear and objective guidance for stakeholders in the agricultural sector, potentially informing agricultural policy and contributing to the discourse on sustainable agriculture.

In summary, the significance of this research lies in its potential to influence compost optimization, agricultural strategies, and environmental sustainability policies in Indonesia. The study's findings are poised to provide actionable insights for farming practices and have the potential to inform national agricultural policies, particularly in the context of the current challenges facing the availability and cost of chemical fertilizers. Moreover, the research contributes to the broader goal of sustainable agriculture by promoting the use of locally-sourced organic materials.

2. MATERIAL AND METHODS

2.1 Primary study data collection

A comprehensive search of published literature in both English and Indonesian was conducted to identify experiments involving the use of organic matter sources added to cow feces for composting. The search was performed on reputable databases, including google.com, scopus.com, and sciencedirect.com, in March 2023. The chosen keywords for the literature search were: cow dung compost, rice straw, wheat straw, maize straw, rice husk, sawdust, palm, vegetable waste, weeds, and cocoa pod husk.

Table 1. Reference was used in meta-analysis

No.	Reference	Carbon Source	pH	Temperature	C	N	P	K	C/N
1	[9]	Rice Straw			34.63	1.38	1.57	0.19	25
2	[10]	Rice Straw	7.25	31	14.69	0.86			16.8
3	[11]	Rice Straw	7.64		17.53	0.81			
4	[12]	Rice Straw	6.2	25.1	31.1	1.64			19
5	[13]	Rice Straw	7.8	40		0.15	0.42		
6	[14]	Rice Straw	6.8	32	14	0.79	0.21	0.23	17.72
7	[15]	Rice Straw	7	40.7	20.24	1.26			27.36
8	[16]	Rice Straw	8.92		1.06	0.067	11.358	12.39	28.7
9	[17]	Corn Straw	7.88		25.4	14.7			
10	[18]	Corn Straw	9.64						14
11	[19]	Corn Straw	9.7		14	1.6	0.02	1.9	8.6
12	[20]	Corn Straw	9.7		14	1.46	0.31	1.26	23
13	[21]	Rice Husk	7.91	29.27	13.6	2.04	0.94	0.45	
14	[22]	Rice Husk	6.5	25	8.1	0.42			19.14
15	[23]	Rice Husk	6.6	27	31.06	2.18	5.4	1.6	14.25
16	[22]	Sawdust	6.5	25	6.29	0.41			15.21
17	[5]	Sawdust				1.285	0.871	0.87	36
18	[19]	Sawdust	8.1		17.8	1.4	0.02	0.5	12.9
19	[24]	Sawdust	6.8	27.8	7.54	0.69			10.92
20	[25]	Sawdust			21.83	0.83			25.41
21	[26]	Palm Oil: Palm Kernel Cake				2	0.5	0.5	
22	[27]	Palm Oil: empty bunch with Trichoderma					0.81	0.96	
23	[28]	Palm Oil: fronds	7.7	36	22.04	1.88	0.31	0.19	11.79
24	[29]	Vegetable and Fruit Waste: Leaf Waste	6.74	28	31.27	2.35	0.45	0.55	14.49
25	[30]	Vegetable and Fruit Waste: Vegetable waste	6.3	30			1.35	1.23	
26	[31]	Weed: Paitan	7.94		28.28	2.16		2.72	13.08
27	[32]	Weed: S. Natan				1.0833	5.027	0.228333	18.22
28	[26]	Cocoa Pod Husk				1.6	0.3	0.6	
29	[33]	Cocoa Pod Husk	8.7			1.245	0.0003	0.0013	
30	[34]	Cocoa Pod Husk	7.8		20	1.5	1	3.5	

The inclusion criteria for selecting literature were as follows: Published in English or Indonesian, provided a comparison of pH and temperature, presented a comparison of carbon, nitrogen, and C/N ratio, included a comparison of mineral content, specifically phosphorus and potassium, examined the effect of composting time. After the initial search, a screening process was employed based on these criteria, resulting in the identification of 30 relevant articles on Table 1, for further data coding and statistical analysis.

2.2 Characterization and data analysis

Data characterization was carried out to see the characteristics of research articles, both substantively and methodologically. The characterization includes identification of the year of publication of the article, title, researcher's name, journal name, related variables, research process, and effect size. Effect size as 'Hedges' (*d*) was applied to compare the effectiveness of control and herbal treatment. This method was chosen because of its ability to calculate effect sizes, regardless of the heterogeneity of sample sizes, units of measurement, and statistical test results, as well as its suitability for estimating the effect of paired treatment. Each study consisted of 2 groups, namely the control group (*C*) and the experimental group (*E*) [7, 8]. Effect size (*d*) is calculated as:

$$d = \left(\frac{(X^E - X^C)}{S}\right)J$$

where,
X^E: the average value of the experimental group
X^C: the average value of the control group
S: combined standard deviation
J: sample correction factor

The factor *J* as the sample correction factor and *S* as the combined standard deviation has the following formula:

$$J = 1 - \left(\frac{3}{4(N^C + N^E - 2) - 1}\right)$$

$$S = \frac{\sqrt{(N^E - 1)(S^E)^2 + ((N^C - 1)(S^E)^2}}{(N^C + N^E - 2)}$$

where,
N^C: sample size of the control group
N^E: sample size of the experimental group
S^C: standard deviation of the control group
S^E: standard deviation of the experimental group

The variance of Hedges (*Vd*) is obtained by the following formula:

$$Vd = \left(\frac{N^C + N^E}{N^C N^E}\right) + \left(\frac{d^2}{2(N^C + N^E)}\right)$$

These statistical methods were chosen due to their suitability for estimating the effect of paired treatments, considering heterogeneity in sample sizes, units of measurement, and statistical test results.

The cumulative effect size (d_{++}) is formulated as follows:

$$d_{++} = \frac{(\sum_{i=1}^{K} W_i\, d_i)}{(\sum_{i=1}^{n} W_i)}$$

where, w_i is 1/vd. The accuracy of the cumulative effect size (d_{++}) is obtained using a 95% confidence interval, namely $d \pm (1.96 \times \text{sd})$. The calculated effect size will be considered significant if the 95% confidence interval gives results that do not reach a zero value. This data analysis was performed using the Microsoft Excel 2016 application. Furthermore, the data was processed by ANOVA analysis through the SPSS version 22 application to determine the Standard Error Mean (SEM) and the significant level (p-Value).

3. RESULT AND DISCUSSION

This research successfully collected data from 30 selected articles spanning from 2006 to 2022, providing information about various organic carbon sources used in composting cow feces. The types of carbon sources included rice straw, corn straw, rice husk, palm oil, cocoa pod husk, weeds, vegetable/fruit waste, and sawdust. Table 2 presents the meta-analysis results, including effect size, variance from Hedges, and cumulative effect size.

Table 2. Effect size, Variance from hedges and cumulative effect size

No.	Parameters	*d* (Effect Size)	*J* (Sample Correction Factor)	*S* (Standard Deviation Pooled)	*Vd* (Variance from Hedges)	d_{++} (Cumulative Effect Size)
1	pH	0.6063	0.9166	0.3808	0.5204	0.6063
2	Temperature	0.0478	0.9166	14.6686	0.3810	0.04
3	C	0.0579	0.9166	17.2434	0.5001	0.0419
4	N	0.3549	0.9166	1.0566	0.9122	0.3808
5	P	1.0476	0.9166	2.1065	0.4901	1.0549
6	K	-0.0530	0.9166	2.3579	0.4445	-0.0533
7	C/N	0.0224	0.9166	19.9239	0.4444	0.0226
8	Time Composting	-0.0746	0.9166	12.7011	0.4446	-0.0746

Effect size, a metric reflecting the treatment effect or relationship strength, serves as the unit of currency in meta-analysis. Table 2 shows that the P parameter has a very large effect size, pH has a medium effect size, N has a medium effect size, while temperature, C, and C/N have small effect sizes. Parameter K has a negative effect size, suggesting a smaller amount of the observed parameters.

Effect size, a value which reflect the magnitude of the treatment effect or (more generally) the strength of a relationship between two variables, is the unit of currency in a meta-analysis. We compute the effect size for each study, and then work with the effect size to assess the consistency of the effect across studies and to compute a summary effect. While Table 2 provides effect sizes, it is crucial to delve into their practical significance. The P parameter exhibits a very large effect size for the composting process, but its practical implications on cow feces compost quality or the composting process itself need elucidation. A more in-depth explanation of the practical implications of each parameter's effect size would enhance the interpretation. Temperature, C, C/N have small criteria. Parameter K have negative effect size, which indicate that using carbon organic source smaller amount of the observed parameters.

The result anova analysis by spss version 22.0 was presented in Table 3.

Table 3. ANOVA analysis

Parameters	Control	Rice Straw	Corn Straw	Rice Husk	Sawdust	Palm Oil	Vegetable and Fruit Waste	Weed	Cocoa Pod Husk	SEM	p-Value
pH	7.40 ± 0.91	7.37 ± 0.86	9.23 ± 0.90	7.00 ± 0.78	7.13 ± 0.85	7.7±0.00	6.52 ±0.31	7.9400±0	8.25 ±0.63	0.13044	0.019
Temperature	29.76±5.73	33.76±6.57	NA	27.09 ±2.13	26.40 ±1.97	36±0.00	29.00 ±1.41	NA	NA	1.08734	0.389
C	17.69±10.12	19.03±11.25	17.80±6.58	17.58 ±11.98	13.36 ±7.64	NA	NA	NA	NA	1.4921	0.857
N	1.41±1.56	0.86±0.55	5.92±7.60	1.54 ±0.97	0.92 ±0.41	1.94 ±0.08	2.35±0.00	1.62 ±0.76	1.44 ±0.18	0.29518	0.075
P	1.47±2.56	3.38±5.34	0.16±0.20	3.17 ±3.15	0.44 ±0.60	0.54 ±0.25	0.90 ±0.63	5.02±0.00	0.43 ±0.51	0.43017	0.643
K	1.70±2.80	4.27±7.03	1.58±0.45	1.02 ±0.81	0.68 ±0.26	0.55 ±0.38	0.89 ±0.48	1.47 ±1.76	1.36 ±1.87	0.4466	0.906
C/N	18.09±9.47	22.43±5.21	15.20±7.27	16.69 ±3.45	20.08 ±10.50	11.79±0.00	14.49±0.00	15.65 ±3.63	NA	1.33317	0.874
Time Composting	50.51±40.05	26.87±13.33	87.00±76.62	39.00±10.14	64.60±64.69	70.00±17.32	35.00±9.89	29.00±1.41	60.33±31.08	6.22263	0.447

The addition of several types of carbon sources to compost has a different pH (p-value<0.05). The addition of carbon sources such as corn straw, palm oil and weeds will increase the pH of the compost compared to the control. Meanwhile, the addition of rice straw, rice husk, sawdust, and vegetable and fruit waste lowered the pH compared to the control. the process of releasing acid, temporarily or locally, will cause a decrease in pH (acidification), while the production of ammonia from nitrogen-containing compounds will increase the pH in the early stages of composting. Organic carbon sources that have high hemicellulose/cellulose, and low lignin will produce high acid and make the pH rather low. The lignin content of rice straw is 6.7% [35], corn straw is 10.60% [36], sawdust is 10.92% [37], palm oil is 19% [38], Cacao Pod Husk 8% [39]. During fermentation, bacterial genus Bacillus, Lactobacillus and Acetobacteria will be produce enzyme to breakdown a carbohydrate, protein, and lipid to be fatty acid, amino acid, pyruvic acid and lactic acid [40]. Acids produced can decreased pH. pH of compost on National Standard Indonesia is neutral [41].

Temperature on composting cow dung with addition carbon source approximately 26-36℃. Temperature on heap composting cow dung as a parameter to be evaluated composting process, after 14 days till 45 a temperature will be decreased approximately 29-32℃ [42]. Temperature be used as one of important parameter to evaluated composting stabilization, because temperature on heap compost related to microbial activity and decomposition rate during composting [43]. Temperature of compost on National Standard Indonesia for compost is equal temperature of groundwater [41]. Temperature of groundwater is 25.2℃ [44].

Carbon content on composting cow dung approximately 13-17%. Carbon organic content from composting break down carbohydrate, protein and lipid. Carbon organic content decreased during composting process, because any carbon loss (CO_2) to air during composting process [45]. Carbon content on compost based National Standard Indonesia approximately 9.80-32% [41]. The addition of several types of carbon sources to compost has a different nitrogen content (p-value<0.1). the addition of types of carbon sources derived from Corn Straw, Rice Husk, Palm Oil, Vegetable and Fruit Waste, Weeds, and Cocoa Pod Husk tends to increase the nitrogen content in compost manure compared to control. Meanwhile, the addition of rice straw and sawdust tended to reduce the nitrogen content in the compost compared to the control. Increasing pH as sign decomposition nitrogen by bacteria to produce ammonia till pH would be base. Increasing pH as sign decomposition nitrogen by bacteria to produce ammonia till pH would be Alkalin [46]. Nitrogen content on compost based National Standard Indonesia minimum 0.40% [41].

Phosphor content on composting cow dung approximately 0.16-5.02%. During composting any aerobic decomposition on phosphor. P-Organic to be H_3PO_4 and $Ca(HPO_4)_2$ [47]. Phosphor content a source carbon material be used on this experiment respectively are 0.04% rice straw [48], 0.25% corn straw [49], 0.3% palm oil [50], 1.23% Cacao pod husk [51], 0.08% sawdust [52]. Phosphor content on compost based national standard indonesia minimum 0.10% [41]. Potassium content on composting cow dung approximately 0.55-4.27%. The presence of potassium nutrients in compost is due to potassium many of which are of organic origin. Organic materials can increase the cation exchange capacity, this is related to the negative charges that come from the $^{-}$COOH and OH groups which dissociates into COO^- and H^+ and O^- + H^+. This negative charge is a potential humus adsorbs cations such as Ca, Mg and K which are bound by force medium, so that it is easily exchanged or undergoes a cation exchange process. Potassium content on compost based National Standard Indonesia minimum 0.20% [41].

Ratio C/N on composting cow dung approximately 11.79-22.43%. During composting process, microorganism need a carbon as energy sources and nitrogen to maintained and built a body cell. the more the compost heap contains nitrogen compounds the more heat is produced and the faster the material decomposes by microorganisms. Triatmojo [45] stated that ratio C/N before composting between 20:1 and 30:1, then it would be decreased till 12:1 so it is suitable for use as fertilizer and is not harmful to plants. Ratio C/N on national standard Indonesian for compost between 10:1 and 20:1 [41]. Time composting cow dung approximately 26-87 days. Microorganisms need time to decompose organic matter. Time composting related to rate decomposition. Rate decomposition/degradation was affected organic material and environment.

4. CONCLUSIONS

Cow dung, when supplemented with organic carbon, demonstrates the potential to yield high-quality compost that meets the stringent standards set by Indonesia (SNI). The choice of organic carbon material significantly influences both the pH and nitrogen content of the compost. The observed correlation between alkaline pH and nitrogen content warrants a detailed exploration of the underlying mechanisms driving this relationship.

In a diverse array of experiments, varying composting times were identified for cow dung combined with different organic materials such as rice straw, weeds, vegetable/fruit waste, rice husk, sawdust, palm oil, and corn straw. To optimize compost quality, future research could delve into identifying the most suitable organic carbon types and establishing the optimal cow dung to organic carbon ratio. Moreover, a deeper investigation into the intricate relationships among pH, nitrogen content, and composting time will contribute to a more nuanced understanding of the composting process.

This study lays the groundwork for future research endeavors, suggesting avenues for exploring alternative organic carbon sources and optimizing additional parameters to further improve the composting process.

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