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Nutrient Analysis of Compost from Different Raw Materials with the Addition of Diaper Waste Hydrogel

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Abstract

Disposable baby diapers are a type of product that is now widely used by the public, but produces large amounts of waste which poses environmental challenges. The way to process this waste is by recycling into additional solid organic fertilizer materials. This study aims to determine the increase in nutrients due to the addition of diaper waste hydrogel to compost products with different raw materials. The parameters observed to measure the quality of the compost are water content, pH, C/N ratio, C-Organic, N, P, K, Ca, Mg, Cu, Zn, and Mn. The study was conducted with different raw materials (sawdust, cow manure and their combination), with and without the addition of diaper waste hydrogel. The results showed that treatments with added diaper waste hydrogel (P1H, P2H, and P3H) had higher macronutrient and micronutrient levels than treatments without (P1, P2, and P3). Especially, P2H treatment had better suitability and nutrient increase compared to other treatments based on SNI 19-7030-2004.

1. INTRODUCTION

Diaper waste is a type of waste that is becoming increasingly common. Diaper waste that is not disposed of properly and is simply left untreated often causes air, soil, and water pollution. Some diaper waste is sometimes wrapped in tight plastic bags to prevent odors and spread of germs, but this causes the diaper waste to be pile up because it is difficult to degrade. Diaper waste is also a type of waste that is often rejected for recycling due to a lack of knowledge about recycling diaper waste.

However, diaper waste still contains high levels of organic matter, such as urine. This organic matter can be used as a source of nutrition for plant growth. Moreover, diaper waste contains Super Absorbent Polymer (SAP). SAP is a component of the hydrogel in diaper products. This material has a very fast absorption capacity for water. This material also allows it to retain water in the soil. The high organic content and ability to retain water are advantages of diaper waste hydrogel and have great potential for recycling into compost products[1].

The use of hydrogel in compostable products is also a recommendation from previous research that plastic parts containing polyethylene and polypropylene in diapers should be recycled and not included in composting [2]. Hydrogel diapers are used as a growing medium and it can increase plant growth because hydrogel contains organic matter such as urine and hydrogel diapers are able to retain water well. The addition of hydrogel diapers also increases humidity due to the long-term retention of water, which will reduce the frequency of plant watering[3].

A higher hydrogel ratio can have a significant effect on increasing the content of macronutrients, namely N, P and K [4]. Besides that, when diaper waste hydrogel is used as a liquid organic fertilizer, the results of nutrient identification still far from the minimum requirements according to Permentan No. 70 of 2011 [5]. Nutrient content of diaper waste hydrogel still needs to be combined with other organic materials to attain the minimum requirements for liquid organic fertilizer.

Previous studies mostly discuss hydrogel as a planting medium or liquid fertilizer, while this study explores its role as an additive in solid organic fertilizer to determine the nutrient content of the fertilizer. This study used sawdust and cow manure compost to add to the diaper waste hydrogel. Both composting materials are readily available and retain high organic matter content. Sawdust contains high carbon reserves, while cow manure contains high nitrogen content. Sawdust and cow manure are often combined with other composting materials, but they lack the water-binding properties of diaper waste hydrogel.

The objective of this study was to evaluate the effect of adding diaper waste hydrogel to compost from different raw materials (sawdust and cow manure) on its nutrient content and overall quality.

2. MATERIALS AND METHODS

The main ingredients for composting are sawdust, cow manure, decomposers, and diaper waste hydrogel. The equipment used included a net basket, basin, shovel, hoe, scales, tarpaulin, stationery, and a set of tools and materials for analyzing compost nutrient content.

The study was conducted with six treatments: P1 (sawdust compost); P2 (cow manure compost); P3 (sawdust compost + cow manure compost); P1H (sawdust compost + diaper hydrogel); P2H (cow manure compost + diaper hydrogel); P3H (sawdust compost + cow manure compost + diaper hydrogel). The study was conducted in several stages:.

a. Preparation

Prepare the composting area and materials. Sawdust is obtained from the furniture industry, while cow manure is obtained from cattle breeders. Cow manure is collected on a tarp and dried for 1 week. Diaper waste hydrogel is obtained by separating the inside of the diaper and collecting it in a lidded container.

b. Compost Making

The composting process is carried out in two stages. The first stage is composting without using hydrogel, namely in P1, P2, and P3. The composting process is carried out by loading the raw materials into the fermenter, then adding decomposer, and so on for the next layer until it fills one-third of the fermenter container. The decomposers used are local microorganisms from fruit skin. An empty container is provided below the fermenter to collect the leachate produced during the composting process. The fermenter is then covered with a tarp. Periodically, each fermenter is stirred to provide aeration during the composting process.

Next, composting stage 2, namely at P1H, P2H, and P3H, by adding hydrogel to the results of composting stage 1 with a ratio of 1:3 for hydrogel and compost. This ratio is based

on the results of pre-research which showed that the compost texture was better at this ratio.

The addition of hydrogel to the compost produced from stage 1 is not added with decomposer. The hydrogel is mixed evenly with the compost and then poured into the fermenter. Periodically, stirring is done to reduce evaporation during the composting process. Each composting stage (stage 1 and 2) is measured the quality of the compost after passing the composting period of 30 days. Parameter measurements include physical and chemical characteristics of compost (C-Organic, C/N ratio, water content, and pH), macronutrients (N-Total, K, P, Ca, Mg) and micronutrients (Cu, Zn, and Mn).

The data obtained then refers to the SNI 19-7030-2004 [6] to determine the suitability of compost after fermentation for 60 days.

3. RESULTS

Parameters that indicate the completion of the composting process can be seen from the maturity of the compost, which includes the physical and chemical characteristics, macro and micronutrient levels of the compost.

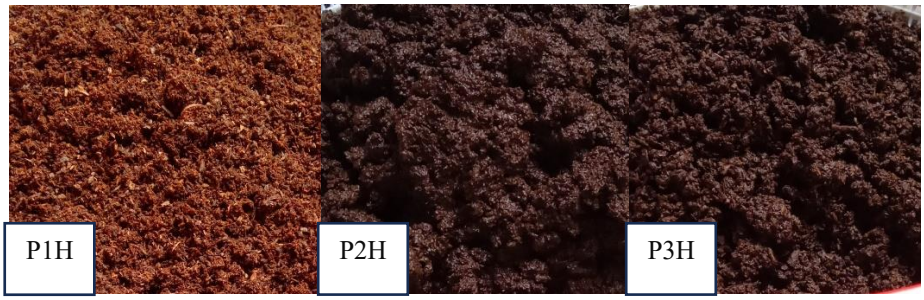

Figure 1. Addition of hydrogel to compost on the first day of the second stage

Hydrogel was added to the compost at 1:3 ratio and decomposed for 30 days. The addition of hydrogel to P1H did not cause the compost texture to become watery, resulting in high absorbency in the compost made from sawdust. Meanwhile, P2H appeared morewatery, possibly due to the compost's raw material consisting solely of cow manure. Conversely, in P3H, the addition of hydrogel prevented the compost texture from being too dry or too wet

Table 1. Physical and chemical characteristics of compost

Parameter	Treatment						SNI 19-7030-2004	
	P1	P2	P3	P1H	P2H	P3H	Min.	Maks.
C-Organic (%)	30.54	20.41	29.04	40.26	17.44	22	9.8	32
C/N ratio	53.57	20.20	40.90	58.34	18.75	22.44	10	20
Water content (%)	37.28	40.17	36.62	39.26	41.03	39.94	-	50
pH	8.68	6.92	7.98	8.58	7.46	7.33	6.80	7.49

Information:
P1: sawdust compost
P2: cow manure compost
P3: sawdust compost + cow manure
P1H: sawdust compost + diaper hydrogel
P2H: cow manure compost + diaper hydrogel
P3H: sawdust compost + cow manure compost + diaper hydrogel

In the treatments given hydrogel, the results of the organic C test showed that P2H (17.44%) and P3H (22%) had lower organic C content percentages compared to P2 (20.41%) and P3 (29.04%). The organic C content containing sawdust (P1H, P1, P3H and P3) had higher organic C content compared to treatments using cow dung as raw material only (P2H and P2). The highest organic C content and exceeded the maximum limit of the SNI standard, namely P1H (40.26%).

In addition to organic C, the C/N ratio is also used to determine the quality of the resulting fertilizer. The C/N ratio in P1H (58.34) has the highest value of all treatments and has exceeded the maximum value threshold of SNI (20). Not only P1H, other treatments containing sawdust also have C/N ratios that exceed the maximum threshold of the SNI standard, namely P1 (53.57), P3 (40.90). Treatments using only cow manure as the raw material, whether with or without hydrogel, have C/N ratios that comply with SNI, namely P2 (20.20) and P2H (18.75).

The pH test results showed that P2H was increasingly neutral, while PIH and P3H showed a pH that decreased from the previous treatments, namely P1 and P3.

Table 2. Macronutrient content of compost

Parameter	Treatment						SNI 19-7030-2004	
	P1	P2	P3	P1H	P2H	P3H	Min.	Maks.
Primary macronutrients								
N-total (%)	0.57	1.01	0.71	0.69	0.93	0.98	0.4	-
P_2O_5 (%)	0.17	0.2	0.29	0.10	0.51	0.36	0.1	-
K_2O (%)	0.8	0.85	1.32	1.41	1.62	1.4	0.2	-
Secondary macronutrients								
CaO (%)	4.89	0.34	0.63	7.70	0.50	0.80	*	25.5
MgO (%)	0.2	0.21	0.27	0.35	0.71	0.44	*	0.6

Information:

***** = The value is greater than the minimum or less than the maximum

P1: sawdust compost

P2: cow manure compost

P3: sawdust compost + cow manure

P1H: sawdust compost + diaper hydrogel

P2H: cow manure compost + diaper hydrogel

P3H: sawdust compost + cow manure compost + diaper hydrogel

Based on the results of the total N content measurements (Table 2), it was found that the addition of diaper waste hydrogel resulted in an increase in nitrogen content. P1 (0.57%) and P3 (0.71%) increased to P1H (0.69%), and P3H (0.98%). However, P2 (1.01%) decreased to P2H (0.98%). Overall, all treatments attain the minimum standard of SNI 19-7030-2004, which is 0.4%.

Measurements of P_2O_5 and K_2O as primary macronutrients, as well as CaO and MgO as secondary macronutrients, showed that treatments with added diaper waste hydrogel (P1H, P2H, and P3H) had higher macronutrient levels than treatments without (P1, P2, and P3). P1H had a significantly higher Ca content than P2H or P3H. Meanwhile, P2H has a higher nutrient value than other treatments, namely P_2O_5, K_2O, and MgO.

Micronutrient measurements were also conducted to determine the quality of the resulting compost. Micronutrients are

nutrients required by plants in small amounts. The results showed that all treatments contained the micronutrients Cu, Zn, and Mn. Zn nutrients were highest in P1H, Mn nutrients were highest in P2H, while Cu did not show any significant difference (Table 3).

Table 3. Micronutrient content of compost

Parameter	Treatment						SNI 19-7030-2004	
	P1	P2	P3	P1H	P2H	P3H	Min.	Maks.
Cu (ppm)	12	9	14	19	19	17	**	100
Zn (ppm)	22	41	62	201	121	87	**	500
Mn (ppm)	39	125	273	54	449	278	**	1000

Information:
P1: sawdust compost
P2: cow manure compost
P3: sawdust compost + cow manure
P1H: sawdust compost + diaper hydrogel
P2H: cow manure compost + diaper hydrogel
P3H: sawdust compost + cow manure compost + diaper hydrogel

4. Discussion

During the composting process, organic compounds decompose, transforming them into humus. This substance is the chemically stable compost material. Safe composting results when the raw materials have been completely degraded [7]. The decomposition of organic material will significantly stabilize carbon. The nutrients in stabilized compost allow for less loss of volatiles (less odor) thus benefiting plant growth [8].

Based on the research results, the results obtained were that organic C levels (carbon) decrease in P2H and P3H from the previous levels in P2 and P3. The addition of hydrogel can help the process of organic C degradation. It is suspected that diaper waste hydrogel contains a number of microbes that help decompose organic C. Degradation of organic C by microbes will cause a decrease in carbon content.

Microbes found in diapers have been isolated and their morphological and physiological characteristics identified as cellulose-degrading bacteria (cellulolytic bacteria)[9]. Cellulolytic bacteria and other microbes decompose organic C into its simplest forms, namely methane and carbon dioxide gas. These gases will evaporate, so that the carbon will decrease.

The longer fermentation process, the carbon will decrease because it has been broken down into simpler compounds by microorganisms [10]. This decrease in carbon value also occurred in a research conducted by which measured the weight reduction of compost, with and without diapers. The results showed that the diaper treatment achieved a slightly higher loss (60%) [2]. Changes in C values also occurred in other studies, including the co-composting of disposable diapers and vegetable waste. The results showed a decrease in C values after the composting process. [11].

However, the addition of hydrogel to P1H did not cause a decrease in organic carbon from the previous level in P1. This is thought to be due to the small proportion of microbes and the characteristics of sawdust which are difficult to degrade. Sawdust tends to be dry and therefore is thought to contain few microbes.

Sawdust can be used as a composting material, although not all of it can be completely decomposed. The harder the type of wood used, the longer the composting

process will take [12]. Therefore, a high organic carbon level indicates a large carbon reserve**.**

Analysis for C/N ratio have similar result with Organis C level. In this study, even though P1H has been added with diaper waste hydrogel containing urine and urine contains nitrogen, it has not been able to reduce the C/N ratio. The still high C/N ratio indicates that the proportion of abundance between nitrogen and carbon does not match the number of available microbes to decomposed.

The treatments containing sawdust are difficult to reduce the C/N ratio because sawdust contains high wood content and low nitrogen. Microbes lack nitrogen for cell growth and cause carbon take a long time to decompose [13]. In addition to the high C/N ratio is caused by the nitrification process being hampered due to a lack of ammonia nitrogen for microorganism replication [14]. If the C/N ratio of the resulting compost is high, nitrogen will be immobilized in the soil by microorganisms, so that nitrogen becomes unavailable [15].

Meanwhile, for the water content analysis, it is obtained in all treatments showed compliance with the provisions of SNI 19-7030-2004 [6]. This means that physically, the compost produced in all treatments showed a similar compost texture, namely not too dry or not too wet. This condition will further improve the ongoing composting process. Measurement results show a higher water content after the addition of hydrogel diapers. This aligns with previous research, which found that the more diapers used in composting, the higher the water content [16]. This parameter is effectively prevented leaching and nutrient loss [17].

Analysis of the pH test results showed that the addition of hydrogel to the compost product brought the compost closer to the normal pH, similar to that of P2H compared to the previous treatment, P2**.**

Meanwhile, P1H and P3H experienced a decrease in pH, although it remained relatively high. This was caused by the organic waste mixed with sawdust which contains lignin and requires a longer composting time.

The further increase in pH was caused by the decomposition of nitrogen-containing organic matter, resulting in the formation of NH_3 , which reacts with water to form NH_4OH [18]. In this study, the still-high pH value is also suspected to be caused by the ongoing decomposition of nitrogen elements and the large amount of carbon reserves that have not been broken down.

Compost production will produce at least some macro and micronutrients in varying amounts depending on the characteristics of the organic material source. For Nitrogen analysis, it was found that the addition of diaper waste hydrogel resulted in an increase in nitrogen content. All treatments attain the minimum standard of SNI 19-7030-2004. Meanwhile, the increase in nitrogen values obtained was not sufficient to achieve an ideal for C/N ratio, as in P1, P3, P1H, and P3H (Table 1).

Diaper waste generally contains urine (74%), feces (14%), and diaper material (12%) [1]. The increase in total nitrogen content was caused by the decomposition of organic matter such as urine. As waste from living organisms, these substances will naturally increase the amount of nutrients such as nitrogen. These results relate to previous research that nitrogen can be obtained from urine contained in diapers. Total nitrogen increased significantly up to day 30 of composting [11].

Not only nitrogen, but other nutrients also increased due to the addition of diaper waste hydrogel. The results of P_2O_5, K_2O and MgO measurements showed that there was an increase in nutrient levels in the treatment given diaper waste hydrogel (table 2). Meanwhile, Ca measurements showed higher results in P1H and P1. This is likely due to the type of compost raw material used (sawdust), which has unique characteristics that increase Ca values.

It is explained that the Ca value will increase in high pH conditions. pH parameters can affect nutrient availability. Substrates with a high pH contain high levels of calcium carbonate [19]. The research results showed that P1 and P1H had higher pH values compared to the others (Table 1). In addition to pH, the C/N ratio in these treatments was also higher than the other treatments. This is due to the relatively high carbon content of the compost raw materials used in P1 and P1H. Therefore, it can be concluded that the higher Ca value is due to the characteristics of the sawdust used as the compost raw material.

Interactions with other nutrients can also affect nutrient measurement results. P1H and P1 had lower phosphorus values than the other treatments. This is because high Ca levels reduce phosphorus availability. Phosphorus availability is reduced by the presence of calcium carbonate, which suppresses the dissolution of calcium phosphates [19].

Based on table 3, it was found that the treatments with the addition of hydrogel had higher nutrient levels compared to the treatments without the addition of hydrogel. Meanwhile, Mn nutrients was highest in P2H and Zn nutrients increased the highest in P1H. The solubility of micronutrients in the decomposition process can be influenced by several factors such as pH conditions and the organic materials used.

Mn was highest in P2H and lower in P1 and P1H. This is due to the characteristic of Mn which is more soluble in more acidic conditions [19]. In the research results obtained, P2H contains optimum pH (neutral) so that the Mn content obtained is higher than treatments with alkaline pH such as P1 and P1H. In contrast, Zn nutrients were higher in P1H due to the characteristic of Zn which is more soluble in alkaline conditions or soil conditions with a more basic pH [19]. The organic materials used also differed between P1, P1H, and P2H. Therefore, organic materials can also affect nutrient measurement results. The addition of diaper waste hydrogel causes an increase in micronutrient concentration, but this increase does not exceed the maximum threshold so that it cannot cause toxicity to plants.

5. Conclusion

Based on SNI 19-7030-2004, P2H showed better results due to its superiority in several parameters, namely the physical and chemical characteristics of compost, macronutrients (P_2O_5, K_2O and MgO) and micronutrients (Mn). Other treatments given hydrogel also showed several advantages. However, the difference in organic materials causes decomposition take longer and nutrient levels can still change. Through composting, hydrogel waste that harbors pathogens, high organic matter, and odors will become easier to manage and provide benefits as an additional ingredient in organic fertilizer. This research still requires further research regarding measurement results calculated with statistical analysis and tested on several types of plants to be more accurate, measurable, and proven.

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