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ORIGINAL ARTICLE

Effect of different ratios of bioplastic to newspaper pulp fibres on the weight loss of bioplastic pot

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Abstract Nowadays, industry is searching for an alternative to reduce the usage of petroleum-based non-degradable conventional seedling plant pots. In this study, three different types of bioplastic pots incorporated with newspaper pulp fibres (the ratio of B75%:N25%, B50%:N50% and B25%:N75% denotes percentage of bioplastic to percentage of newspaper pulp fibres) were produced while B0%:N100% acted as the control. All cylinder square shape moulded bioplastic pots with 100 mm height and 2 mm thickness were planted with *Leucaena leucocephala* seedlings for 60 days in two ground levels (below ground and above ground). Weight loss for bioplastic pots was evaluated. Results showed that bioplastic pots tested below ground had a higher percentage of weight loss than those planted above ground. For percentage of weight loss of bioplastic pots, most bioplastic pots that were tested in both ground levels only showed a significant difference at $p \leqslant 0.05$ after 30 days. Bioplastic pots B75%:N25% that were tested below ground have the highest percentage of weight loss with 77.93%. As conclusion, B50%:N50% is the most suitable ratio for the production of bioplastic pot.

1. Introduction

Population growth has increased the growth in agricultural activities thus increasing the generation of agricultural wastes indirectly. One of the most common wastes generated is the petroleum-based conventional seedling plant pots or polybags as these pots are the most common pots used in plantations. Normally these non-biodegradable pots were disposed after use and end up in landfills which will cause pollution. In order to solve this issue, the plantation industries are searching for an alternative for the usage of non-biodegradable seedling plant pots.

Population growth had also increased solid waste generation such as organic waste, paper, plastic, rubber, metal, wood, glass, ceramics and textiles. Most of these solid wastes including newspaper end up in landfills as this is the most common method used for the disposal of solid waste in Malaysia. As the level of environment awareness increases, public starts to recycle used newspaper with the help of new technology. These recycled newspaper pulp fibres are used as the source of biofibre materials for construction, newsprint, paperboard packaging, insulation or building materials (Huda et al., 2005). In

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order to maximize the usage of recycled newspaper pulp fibres, industries are exploring more usage of these fibres into other products. One of these products would be the bioplastic pot which is a mixture of bioplastic and newspaper pulp fibres which may become an alternative for the non-degradable seedling plant pot. Moreover, the presence of bioplastic and newspaper pulp fibres can produce degradable pots with a higher durability. Besides, bioplastic contained in the pots can reduce swelling of pots caused by water absorption during production and planting process. In this study, production of bioplastic pot by incorporating newspaper pulp fibres into bioplastic was evaluated for its weight loss for pots made from different ratios of bioplastic and newspaper pulp fibres for planting above and below ground.

2. Materials and methods

2.1. Preparation of raw materials

Materials used for the production of bioplastic pot were newspaper, tapioca starch (or known as cassava starch), glycerol with 99.5% concentration and vinegar. Newspapers were collected from several sources normally in the recycling activity and soaked overnight in water. Soaked newspapers underwent fibrillation process by using a valley beater for five minutes.

2.2. Production of bioplastic

Materials for the production of bioplastics were tapioca starch, water, vinegar and glycerol. First, appropriate amounts of materials for bioplastic pot were weighed based on ratio of bioplastic and newspaper pulp fibres. Control of purely newspaper pulp fibres was also produced. Secondly, tapioca starch, water, vinegar and glycerol were mixed together in room temperature. After that, fibrillated newspaper pulp fibres were added into the mixture and stirred for two minutes until all materials were mixed well. Lastly, bioplastic and newspaper pulp fibre mixture was heated on hot plate at 80 °C temperature until obtain sticky gel texture based on dee Thomas (2011).

2.3. Production of bioplastic pot

There were three different types of mixing ratios between bioplastic and newspaper pulp fibres which were B75%:N25%, B50%:N50% and B25:N75%. Pot made from 100% of newspaper pulp fibres acted as control. Numbers of duplicates produced were 80 for each variable including control.

In order to get uniform size and shape of pot, stoppers of 2 mm were used in the formation of bioplastic pot. Mixture of bioplastic with newspaper pulp fibres was spread evenly on an aluminium foil. Then, the spread of bioplastic and newspaper pulp fibre mixture was dried in an oven at 70 °C temperature . Drying time of the spread was varied according to different ratios of bioplastic and newspaper pulp fibre mixture as shown in Table 1. The purpose of drying spread of bioplastic and newspaper pulp fibre mixture was to enable the process of spread removal from aluminium foil easier.

Table 1 Drying time of spread of bioplastic and newspaper pulp fibre mixture.

Ratios of bioplastic and newspaper pulp fibres	Drying time (minutes)
B75%:N25%	15
B50%:N50%	10
B25%:N75%	5
B0%:N100% (control)	0

After that, the spread of bioplastic and newspaper pulp fibre mixture was removed from aluminium foil and formed by using cylinder square mould. Formed bioplastic pots were dried in an oven at 70 °C for 24 h in order to achieve equilibrium with temperature and humidity of the surrounding. Shape of bioplastic pot was cylinder square with 35 mm width, 100 mm height and 2 mm thick.

2.4. Testing of bioplastic pot

Firstly, initial weight of bioplastic pots was taken. Then, *Leucaena leucocephala* seedlings were planted in bioplastic pots and their initial heights were measured. A total of 40 bioplastic pots from each variable with planted seedlings were tested below soil in order to test the degradability of the pot with soil contact. Another 40 bioplastic pots from each variable with planted seedlings were tested above ground in order to test the degradability of bioplastic pot above ground. Then, cleaned bioplastic pots were dried at 50 °C for 24 h in oven based on Singh and Sharma (2008). Dried bioplastic pots were left for 24 h. Weight of dried bioplastic pots was measured. The process of drying continued until dried bioplastic pots obtained stable weight. Percentage weight loss of pot was calculated by using the formula below based on Liu et al. (2010):

$$\text{Weight loss}(\%) = \frac{W_i - W_f}{W_i} \times 100\%$$

W_i = Initial oven-dry weight (g)
W_f = Final oven-dry weight (g)

3. Results and discussion

Bioplastic pot B75%:N25% has an average initial weight of 10.76 g while bioplastic pot B50%:N50% is 11.5 g. The average initial weight of bioplastic pots B25%:N75% and B0%:N100% (Control) is 10.18 and 3.50 g, respectively.

Descriptive statistics (mean and standard deviation) and result for Post Hoc Test (Tukey HSD) at 95% of confidence interval for percentage of weight loss for bioplastic pots with different ratios of bioplastic and newspaper pulp fibres which were tested at different ground levels and harvested at different time intervals are shown in Table 2.

Weight loss of all bioplastic pots that were tested below ground only showed significance difference where $p \leqslant 0.05$ after 30 days of planting except for bioplastic pots B75%:N25% (Table 2). On the other hand, all bioplastic pots that were tested above ground also only showed significance difference where $p \leqslant 0.05$ after 30 days of planting. This may be due to the fact that the microorganism that will only grow rapidly after 30 days. In the study of "Analysis of biodegradability of three biodegradable mulching films", Liu et al. (2010) only observed microbial growth on samples that had been inoculated with soil suspension after 28 days. Hence, duration of soil burial testing

Table 2 Percentage of weight loss for bioplastic pots (B75%:N25%, B50%:N50%, B25%:N75% and B0%:N100%) that were tested at different ground levels (below ground and above ground) and harvested at different time intervals (15, 30, 45 and 60 days).

	Bioplastic pots		Time (days)			
			15	30	45	60
Weight loss (%)	B75%:N25%	Below ground	$21.83^{a}_{v} \pm 6.25$	$34.47^{ab}_{v} \pm 10.96$	$43.99^{b}_{v} \pm 12.96$	$77.93^{c}_{v} \pm 22.11$
		Above ground	$24.90^{a}_{v} \pm 4.73$	$31.12^{ab}_{v} \pm 6.98$	$40.27^{b}_{v} \pm 10.64$	$46.93^{b}_{w} \pm 9.50$
	B50%:N50%	Below ground	$10.05^{a}_{w} \pm 2.73$	$20.62^{a}_{w} \pm 3.43$	$46.86^{b}_{vy} \pm 13.16$	$61.78^{b}_{vw} \pm 25.84$
		Above ground	$16.54^{a}_{vx} \pm 2.77$	$20.79^{ab}_{w} \pm 2.25$	$28.52^{b}_{vw} \pm 6.59$	$38.33^{c}_{wx} \pm 10.73$
	B25%:N75%	Below ground	$4.88^{a}_{wy} \pm 3.54$	$14.81^{a}_{wx} \pm 8.14$	$50.06^{b}_{wy} \pm 23.34$	$68.80^{b}_{vw} \pm 28.03$
		Above ground	$6.39^{a}_{w} \pm 3.47$	$8.79^{ab}_{x} \pm 3.49$	$15.33^{b}_{wx} \pm 5.90$	$25.58^{c}_{wx} \pm 8.63$
	B0%:N100% (Control)	Below ground	$5.20^{a}_{wy} \pm 5.11$	$17.00^{a}_{wx} \pm 0.88$	$65.10^{b}_{y} \pm 22.89$	$85.07^{c}_{v} \pm 9.43$
		Above ground	$0.67^{a}_{y} \pm 0.49$	$1.13^{a}_{x} \pm 0.79$	$4.70^{a}_{x} \pm 4.60$	$17.53^{b}_{x} \pm 8.47$

Notes: ± denotes standard deviation.
The different alphabets a, b, c and d in each row for the same ratio at the same ground level measured at a different time interval is significant at $p \leqslant 0.05$.
The different alphabets v, w, x and y in each column for the different ratio at the same ground level measured at the same time interval is significant at $p \leqslant 0.05$.

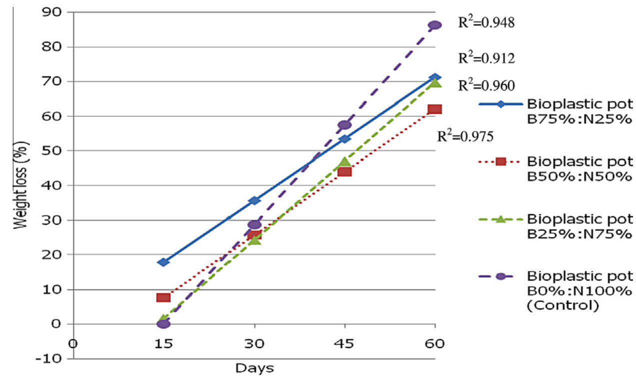


Figure 1 Trend graph for weight loss of bioplastic pots with different ratios of bioplastic and newspaper pulp fibres that were tested below ground and harvested at different time intervals.

must be more than 30 days in order to obtain significance difference.

Weight loss of bioplastic pots B75%:N25% ($R^2 = 0.912$) which was tested below ground was the highest among other bioplastic pots for 15 and 30 days with 21.83% and 34.47% of weight loss, respectively (Fig. 1). Highest content of tapioca starch in bioplastic pot B75%:N25% may increase the degradation rate of the bioplastic pot. This may be relevant with the research done by Liu et al. (2010) that showed the degradation rate of biodegradable mulching film made from highest content of destructurized starch complexed with Poly (e-caprolactone) (PCL) is highest compared to biodegradable mulching films with lower content of modified starch in soil burial test. However, the control that was tested below ground had the highest percentage of weight loss after 45 and 60 days of planting with 65.10% and 85.07% of weight loss, respectively. This may be due to the weak structure of hydrogen bond in the control compared to other bioplastic bonded pots. Presence of ink or other newspaper additives may reduce the strength of bioplastic pots because these materials may have a negative effect on fibre–matrix interactions or tend to produce fibre aggregations (Baroulaki et al., 2006). Besides that, bioplastic contained in bioplastic pots helps to increase the strength of bioplastic pots. Control

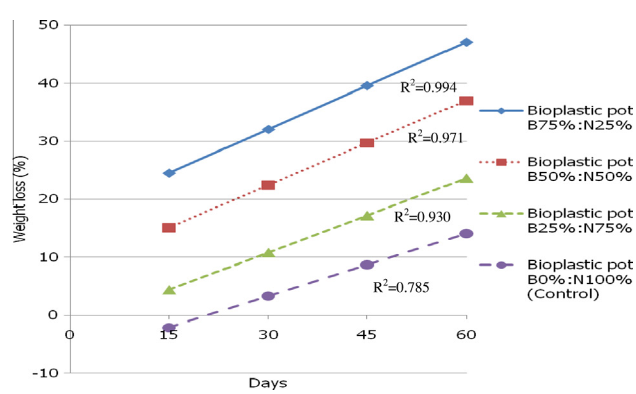


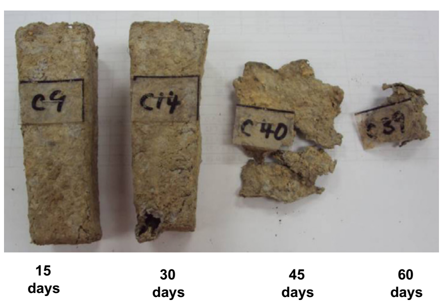
Figure 2 Trend graph for weight loss of bioplastic pots with different ratios of bioplastic and newspaper pulp fibres that were tested above ground and harvested at different time intervals.

(a) Bioplastic pots B75%:N25% (below ground).

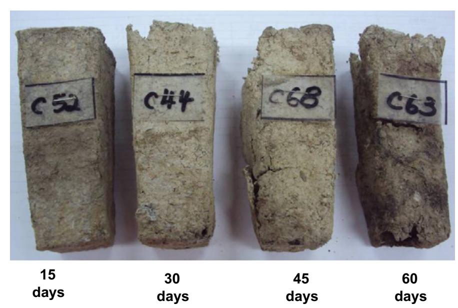
(b) Bioplastic pots B75%:N25% (above ground).

(c) Bioplastic pots B50%:N50% (below ground).

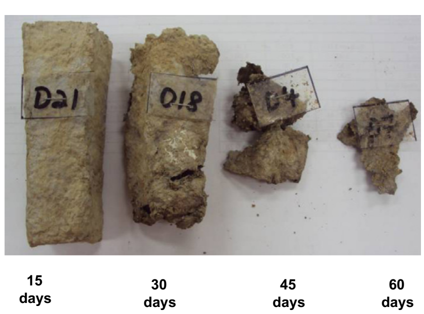
(d) Bioplastic pots B50%:N50% (above ground).



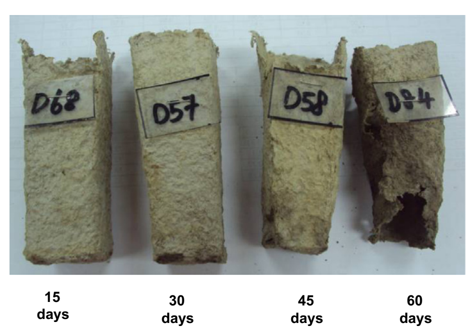
(e) Bioplastic pots B25%:N75% (below ground).



(f) Bioplastic pots B25%:N75% (above ground).



(g) Bioplastic pots B0%:N100% (below ground).



(h) Bioplastic pots B0%:N100% (above ground).

Figure 3 Bioplastic pots with different ratios which were planted at different ground levels and harvested at different time intervals.

which does not have bioplastic contents has a higher weight loss than other bioplastic pots.

On the other hand, bioplastic pots B75%:N25% (R^2 = 0.994) which were tested above ground had the highest weight loss for 15, 30, 45 and 60 days with 24.90%, 31.12%, 40.27% and 46.93% of weight loss, respectively (Fig. 2). As stated earlier, highest content of tapioca starch in bioplastic pot B75%:N25% may increase the degradation rate of bioplastic pot.

Fig. 3 shows visually that percentage of weight loss for bioplastic pots which were tested below ground was higher that percentage of weight loss for bioplastic pots which were tested above ground. The highest weight loss of bioplastic pots that were tested below ground is 77.93% after 60 days whereas the highest weight loss of bioplastic pots that were tested above ground is 46.93%. Soil moisture content, soil temperature, soil pH and soil enzymes and microorganisms are factors that affect the rate of naturally occurring biodegradation (Kyrikou and Briassoulis, 2007; Liu et al., 2010). Higher water content which provides optimum condition for fungal growth may cause a higher degradable rate of bioplastic pots that were tested below ground compared to pots that were tested above ground. Moreover, higher percentage of microorganism presence such as fungi may help to increase the degradation rate of bioplastic pots tested below ground. In a study done by Liu et al. (2010), degradable rate of biodegradable mulching film added with soil suspension in microorganism culture was higher than biodegradable mulching film without soil suspension. This is proved with evidence that showed the presence of microorganisms (fungi, bacteria and Actinomycetes) in culture medium with soil suspension was higher than culture medium without soil suspension. Besides that, the presence of organisms such as ants and termites which consumed bioplastic pots helps to increase the degradation rate of bioplastic pots that were tested below ground. Moreover, the presence of millipedes and snails in soil caused damages on bioplastic pots such as producing small holes on bioplastic pot tested below ground. Therefore, percentage of weight loss of bioplastic pots which were tested below ground is higher than bioplastic pots that were tested above ground.

All different types of bioplastic pots that were tested at different ground levels show high increment in the percentage of weight loss as time of planting increased. Control has the highest rate of increment for percentage of weight loss with 1616.43% and 2237.84%, respectively for below ground and above ground from 15 to 60 days of planting. Bioplastic pots B25%:N75% have the second highest rate of increment for percentage of weight loss with 1282.15% and 289.60% for below ground and above ground, respectively. The rate of increment for percentage of weight loss for bioplastic pots B50%:N50% which were tested below ground and above ground is 505.39% and 131.17%, respectively. Lastly, bioplastic pots B75%:N25% that were tested below ground showed an increment of 242.45% in percentage of weight loss and 85.53% for above ground. This may be because control is the weakest pot among other bioplastic pots. Baroulaki et al. (2006) stated that the presence of ink or other newspaper additives may reduce the strength of pots because the presence of these materials may have a negative effect on fibre–matrix interactions or tends to produce fibre aggregations (Baroulaki et al., 2006). Besides that, higher fibre concentration may also reduce the strength of the bioplastic pot. A study done by Baroulaki et al. (2006) showed that the strength of low density polyethylene (LDPE) and paper composites decreased as paper concentration increased. The study also stated that composites with higher paper concentration may face problems such as impeded interaction between fibres and LDPE matrix and higher chance of formation of fibre aggregates. Besides that, bioplastic is able to increase the strength of the bioplastic pot and duration of usage. Therefore, control which had no content of bioplastic at all will have low strength. Moreover, the presence of higher moisture content and soil organisms below ground caused control to become more susceptible to damage.

4. Conclusion

In conclusion, this study showed that bioplastic pots with different ratios of bioplastic and newspaper pulp fibres which were tested at different ground level had different degradation rates. Overall, weight loss of bioplastic pots tested below ground is higher than bioplastic pots tested above ground. Besides that, result shows that the bioplastic pot B75%:N25% has the highest weight loss (77.93%) when tested below ground and 46.93% of weight loss when tested above ground. A fungus named Deuteromycetes found on bioplastic pot may help in the degradation of bioplastic pot. Moreover, organisms such as ants, termites, millipedes and snails may also cause degradation of bioplastic pots.

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