International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

CHARACTERISATION OF EMPTY FRUIT BUNCH (EFB), TAPIOCA AND WOOD FIBRE DERIVED BIODEGRADABLE DISPOSABLE PLATES (bDPs)

Murugan P.[1]*, Rosenani A.B[1], S.A. Hajar[2], and Halimi Mohd Saud[3].

[1]Department of Land Management, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

[2]Department of Crop Science, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

[3]Department of Agriculture Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

*Corresponding author

ABSTRACT

Polystyrene is one of the most widely used food packaging materials in the form of disposable plates and containers. Due to the stable structure of polystyrene, it is not degraded easily and causes accelerated occupancy of the landfills. Recent regulations stipulated by Government of Malaysia to use of biodegradable disposable packaging materials (BDPMs) in Kuala Lumpur will increase the amount of BDPMs dumped at the landfills. This study assessed the chemical and physical properties of biodegradable disposable plates (BDPs) available in Malaysian market to determine the potential viability to be decomposed in soil and reutilise the available nutrients. Three types of BDPs made from wood fibre, oil palm empty fruit bunch (EFB), and tapioca were used in the study. The pH of the BDPs ranged from 5.13 to 7.83. The C/N ratio ranged from 158 to 257.The percentage of Ca, Mg and K ranged between 0.85 to 2.15 %, 0.03 to 0.39 % and 0.13 to 0.18% respectively. The concentration of the micronutrients (Pb, Cd , Mn , Zn, Fe, Cu, Al , and Ni) were all below the permitted range for compost. All three BDPs showed the ability to be recycled with substantive amount of nutrients contained for reutilisation upon degradation in soil.

Keywords: Biodegradable disposable plates, Agriculture wastes, Agricultural waste management, Empty fruit bunch.

1. INTRODUCTION

The conventional disposable food and beverage packaging material such as plastics and polystyrene have been used for decades in the food and beverage industry. Global production

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

and consumption of polystyrene (all grades) in 2009 were approximately 14.4 to 14.9 million metric tonnes, respectively (World Petrochemical Report, 2010). Polystyrene takes hundreds of years to degrade. As a consequence several thousands of tons of goods, made on plastic materials, are land filled, increasing every year the problem of municipal waste disposal (Kirwan & Strawbridge, 2003). According to Abdul Khalil et al. (2016), the use of these non-biodegradable and non-renewable materials, i.e., glass, metals, and plastics) in packaging applications has raised public concerns about environmental pollution. As cited by Abdul Khalil et al. (2016) as well, there is demand for the safe management of such wastes. Large quantities of these packaging materials are manufactured every year with the intention of use and throw. Thus, these packaging materials will end up in the landfill, occupying the space and shortening the lifespan on the landfills.

In line with such concerns, the Malaysian Government had also announced initiatives from inception of “No Plastics Day” campaign in the year 2010 and then perpetually covered a wider scope of polystyrene bans in a few states, including the implementation in Kuala Lumpur in the year 2017 (New Straits Time Online, 2017).

Currently, in the Malaysian market, there are several types of BDPs used as disposable food and beverage packaging materials manufactured from plant based packaging materials, i.e, residues from agriculture activities such as empty fruit bunch, tapioca starch and wood industries, rich in plant nutrients. Due to the recent enforcement from the Government, there will an increase in the amount of BDPs where most will discarded in the landfill together with the other wastes but the number of studies undertaken on the characterisation of physical and chemical composition of BDPs from different sources available in the market for the decomposition and recycling purposes is very scarce. This is because the materials are plant-based and rich in nutrients, they can be allowed to decompose in soil and the nutrients may be recycled into the soil to be used as a planting media instead of sending to the landfill. A study was carried out to determine the physical and chemical characteristics of BDPs available in the local market, i.e., EFB BDPs, tapioca BDPs and wood fibre BDPs in determining the potential viability to be decomposed in soil and reutilise the available nutrients.

2. RESEARCH METHODS

A survey was conducted on the available biodegradable packaging (BDPs) in the domestic market. It was found that there were tapioca starch, EFB and wood fibre based BDPs already present at the Malaysian market in the year 2010. The BDPs plates were collected from different sources, plates of tapioca-derived BDPS from Natures Harmony Industries Sdn Bhd, EFB-derived BDPs were bought from a convenient store at Ampang, Kuala Lumpur and inkless plates from wood fibre-derived BDPS were bought from Giant Hypermarket, Taman Sri Manja,

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

Petaling Jaya, Selangor (Figure 1). The WF BDPs chosen for this experiment was without any coloured imprints to eliminate the effect of dyes from print from not affecting the results.

Tapioca BDPs EFB BDPs Wood Fibre BDPs

Figure 1: Tapioca, EFB and Wood Fibre Derived BDPs

2.1 Preparation of samples

The plates of BDPs with the diameter of 15.25 cm were cut using scissors into pieces of approximately with dimensions of 2 cm × 2 cm and were placed in brown paper bags before being oven dried for 24 hours at the temperature of 105°C. The dried BDPs were then cut and ground using lab-scale grinder.

2.2 Physicochemical characterization of EFB, TP and WF BDPs

The mechanical strength such as tensile strength (TS) of the BDPs were investigated using tensile machine, referring to standard method ASTM D 638-03 (Salehudin *et al*., 2014. The pH (water) was determined in the suspension of 1:5 (tissue: water) using pH-meter (Mettler MP 225). Moisture content was determined by gravimetric method. Total C was analysed using CNS Analyser (LECO Truspec Micro Elemental Analyzer CHNS, New York). Total N of the BDPs were determined using Kjeldhal method (Bremner and Mulvaney, 1982) and the N content in the sample was determined using the Quickchem auto-analyzer FIA 8000 (Lachat Instrument, USA). The macro- and micronutrient contents of the BDPs were determined using dry ashing method (Campbell and Plank, 1998) and were analysed using the atomic absorption spectrophotometer (PerkinElmer PinAAcle 900T) while Al, Pb, Cr, Ni and Cd were analysed using the inductively coupled plasma (ICP) spectrophotometer. Lignin, cellulose and hemicellulose content were determined using Van Soest method (Van Soest *et. al*., 1991).

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

2.3 Data Analysis

Variables on the chemical characteristics were analysed using ANOVA and the treatment means were compare with Duncan's Multiple Range Test (DMRT) at $p<0.05$. All statistical analysis was performed using Statistical Analysis System (SAS) Version 9.2.

3. RESULTS

3.1 Physical Characteristics of EFB, Tapioca and Wood Fibre BDPs

Table 1: Moisture content and mechanical strength of BDPs derived from EFB, TP and WF

BDPs	Tensile Strength (TS) (N/mm^2)	Moisture content (%)
WF	39.4a	0.9a
EFB	43.5a	0.7b
TP	0.8b	0.4c

Means with different letters within the column indicate significant differences ($p<0.05$) using Duncan's Multiple Range Test (DMRT). Note: WF=Wood Fibre; EFB= Empty fruit bunch; TP= Tapioca.

Both WF and EFB BDPs were physically stronger than TP BDPs due to their fibrous structure. The TP BDPs have almost similar physical properties as polystyrene where it is easily breakable. The EFB BDPs is also more water resistant for longer period of time compared to WF BDPs and TP BDPs where it becomes wet and soggy. The tensile strength of EFB BDPs and WF BDPS are significantly higher compared to TP BDPs. The tensile strength of EFB BDPs was 43.5 N/mm^2 whereas WF BDPs 39.4 N/mm^2 and TP BDPS 0.8 N/mm^2. The moisture content of all the BDPs were insignificantly low (<1 %) but WF recorded the highest moisture content as in Table 1.

3.2 pH and Ligno-cellulosic Content of EFB, Tapioca and Wood Fibre BDPs

Table 2: Ligno-cellulosic content (% w/w-dry weight basis) and pH of BDPs made from EFB, TP and WF

BDPs	Cellulose	Hemicellulose	Lignin	pH
	------------------------------	(%)	------------------------------	
WF	39.4b	24.9b	23.8b	7.7a
EFB	43.5a	28.3a	27.6a	7.6a
TP	12.3c	5.9c	2.6c	5.1b

Means with different letters within the column indicate significant differences ($p<0.05$) using Duncan's Multiple Range Test (DMRT). Note: WF=Wood Fibre; EFB= Empty fruit bunch; TP= Tapioca.

The cellulose, hemicellulose, and lignin content were the highest in EFB BDPS followed by WF and Tapioca derived BDPs per Table 2. The cellulose content of the three BDPs is significantly different from one another where EFB BDPs> WF BDPs> TP BDPs. The hemicellulose content between the EFB and WF is not significantly different to one another but both are higher that TP. Chang *et al*. (2014) cited that some of the studies suggested the content of cellulose, hemicellulose and lignin in EFB are within a certain range in EFB, which typically comprises of cellulose (24-65%), hemicellulose (21-34%) and lignin (14–31%). pH of BDPS derived from WF, EFB and TP ranged from 5.1 to 7.7. TP BDPs gave the lowest pH while there were no significant differences in pH between BDPs derived from WF and EFB.

3.3 Macronutrient Content of the EFB, Tapioca and Wood Fibre BDPs

Table 3: Total Carbon, Total Nitrogen and Macronutrients contents (wt. %) of BDPs plates made from EFB, TP and WF

BDPs	Total C	Total N	C/N	Ca	P	Mg	K
	------------(%)----------		ratio	------------------------------(%)------------------------------			
WF	51.57a	0.33a	156b	1.38b	2.83a	0.21b	0.18a
EFB	29.34b	0.16b	183ab	0.85c	0.16c	0.03c	0.13a
TP	47.17ab	0.18b	262a	2.15a	1.26b	0.39a	0.18a

Means with different letters within the column indicate significant differences ($p<0.05$) using Duncan's Multiple Range Test (DMRT). Note: WF=Wood Fibre; EFB= Empty fruit bunch; TP= Tapioca.

Based on results in Table 3, there were significant differences in the percentage of total C among the treatments where both EFB BDPs and TP BDPs are significant to each other whereas the WF BDPs falls in between both the BDPs. The EFB BDPs had higher N compared to WF and TP where in terms of significance, both TP and WF BDPs are significantly different from EFB BDPs. The C/N ratio in all the BDPs ranged from 156 to 262. There were significant differences among the treatment where TP BDPs had the highest C/N ratio 262 compared to EFB BDPs and WF BDPS. TP BDPs had higher Calcium concentration compared to EFB and WF BDPs where they were significantly different from each other in the following order TP BDPs >WF BDPs>EFB BDPs. The percentage of Mg in the BDPs was significantly different among each other where TP BDPs contained the highest compared to EFB and WF BDPs, in the following order of TP BDPs>WF BDPs>EFB BDPs. There were no significant differences between the BDPs in K concentration which ranged from 0.13% (EFB BDPs) to 0.18% (WF and TP BDPs).

3.4 Micronutrient Content of the EFB, Tapioca and Wood Fibre BDPs

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

Table 4. Micronutrients Concentration in BDPs made from EFB, TP and WF

Treatments	Mn	Zn	Fe	Cu	Cr	Al	Pb	Cd	Ni
					(mg kg^{-1})				
WF	7.67b	8.00b	205b	3.93ab	0.28a	172b	1.97c	0.77a	5.95a
EFB	14.33a	18.67a	716a	5.33a	0.08c	319a	6.09a	0.50a	0.48c
TP	1.33c	3.67c	16c	2.37b	0.11b	7c	5.37b	0.80a	1.42b

Means with different letters within the column indicate significant differences ($p<0.05$) using Duncan's Multiple Range Test (DMRT). Note: WF=Wood Fibre; EFB= Empty fruit bunch; TP= Tapioca.

Based on the results in Table 4, there were significant differences shown in the concentrations of Mn, Zn, Fe, and Al among the different types of BDPs in the following order EFB BDPs>WF BDPs>TP BDPs whereas both Cr and Ni also showed significant difference among the treatments in the following order of WF BDPs>TP BDPs>EFB BDPs. The concentration of Pb also showed significant difference in the following sequence EFB BDPs>TP BDPs>WF BDPs and lastly the concentration of Cd was relatively low and did not differ between the BDPs significantly.

4. DISCUSSION

In terms of the physical appearance, all three BDPs could be used for food packaging due to their hardness, but TP BDPs tends to be brittle in terms of structure compare to WF BDPs and EFB BDPs. This is justified by the higher tensile strength and ligno-cellulolisic content of WF BDPs and EFB BDPs compared to TP BDPs due to its fibrous nature. According to Hladíková (2015), both cellulose and hemicellulose could biodegrade fast, while lignin will degrade slowly by microorganisms due to its complex structure. Both EFB and wood fibre contained significantly higher amount of cellulose, hemicellulose and lignin compared to tapioca derived BDPs which led to the higher tensile strength (Tarrés *et al*., 2017).

There were no significant difference in terms of pH between WF and EFB BDPs, where both exhibited alkaline pH whereas TP BDPs exhibited acidic pH. According to Demiate *et al*. (2011), the common pH values recorded in the other studies of tapioca starch ranges from 2.79 ± 0.14 to 6.11 ± 0.23. The alkaline pH of wood fibre and EFB BDPs in return will increase the increase the soil pH upon decomposition, which is suitable for plant growth. Moreover, the EFB BDPs also contains high concentration of N and P that is valuable and justifies the recycling efforts instead of sending to the landfills. These differences in pH also might be due to the chemical binders used in the manufacturing of the respective BDPs.

There were also significant differences in the percentage of C among the treatments. The EFB BDPs had the highest C percentage compared to WF and TP BDPs. The high percentage of C is

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

due to the high content of cellulose in these BDPs. The EFB BDPs had higher N % compared to WF and TP. The C/N ratio of the BDPs will influence the decomposition rate. The highest C/N ratio was found in WF BDPs and followed by EFB BDPs and TP BDPs. Using traditional composting methods, EFB may take months or years to reach maturation. The high C/N ratio is due the presence of polymers such as lignin and cellulose in EFB and WF BDPs act as inhibitor against natural biodegradation (Gaind et al., 2007).

According to the published EU Directive 94/62/EC (amended by 2004/12/EC) on Packaging and Packaging Waste, the permitted concentration of heavy metals is at a maximum limit of 100 mg/kg for Pb, Cr and Cd in packaging materials where all the three samples were within the range.

5. CONCLUSION

It can be concluded that the BDPs vary in their chemical and physical characteristics according to the different feedstock, i.e., EFB, tapioca and wood fibre. The difference in the chemical properties such as lignocellulosic content led to the variation in the physical properties of the BDPs. The pH of both EFB and wood fibre were both slightly alkaline compared to TP BDPs, which was acidic. The alkaline pH of wood fibre and EFB BDPs in return will increase the soil pH upon decomposition, which is suitable for plant growth. Further studies will be conducted to determine the decomposition of the BDPs in soil and nutrients reutilisation.

REFERENCES

Beeson, R.C.J. 1996. Composted yard waste as a component of container substrates. *J. Environ. Hortic.* 14:115–121

Bremner, J.M. and Mulvaney, C.S. 1982. Total nitrogen. In: Methods of Soil Analysis, eds. A.L. Page, R.H. Miller, and D.R. Keeny, pp. -111923. American Society of Agronomy and Soil Science Society of America, Madison.

Campbell CR, Plank CO. 1998. Preparation of plant tissue for laboratory analysis. Chapter 3. In: Kalra YP, editor. Handbook of reference methods for plant analysis. Boca Raton, Fl. CRC Press; p. 37-49.

Davis G. and Song J.H. 2006. Biodegradable packaging based on raw materials from crops and their impact on waste management.Ind. Crops Prod., 23 (2006), pp. 147–161

Demiate Ivo Mottin, Valesca Kotovicz. 2011. Cassava starch in the Brazilian food industry. Food Science and Technology (Campinas)Ciênc. Tecnol. Aliment. vol.31 no.2 Campinas Apr./June 2011

ISSN: 2455-6939

Volume:04, Issue:03 "May-June 2018"

Eklind, Y., B. Raemert and M. Wivstad. 2001. Evaluation of growing media containing farmyard manure compost, household waste compost or chicken manure for the propagation of lettuce (*Lactuca sativa* L.) transplants. *Biol. Agric. Hortic*. 19: 157–181.

Gaind S., Pandey A.K., Lata J. 2006. Microbial biomass: p-nutrition and enzymatic activities of wheat soil in response to phosphorus enriched organic and inorganic manures, J. Environ. Sci. Health Part B 41 177–187

Hashemimajd, K., M. Kalbasi, A Goichin and H. Shariatmadari. 2004. Comparison of vermicompost and composts as potting media for growth of tomatoes. J. Plant Nutr. 27:1107–1123.

Hladíková Z., Kejlová K., Sosnovcová J., Jírová D., Vavrouš A., Janoušek A., Syčová M., Špelina V. 2015. Microbial contamination of paper-based food contact materials with different contents of recycled fiber. Czech J. Food Sci., 33: 308–312

Kirwan, M. J., & Strawbridge, J. W. 2003. Plastics in food packaging. Food Packaging Technology. Blackwell Publishing, Oxford, pp. 174-220

Körner I., Redemann K., and Stegmann R. 2005. Behaviour of biodegradable plastics in composting facilities Original Research Article Waste Management, Volume 25, Issue 4, Pages 409-415

Salehudin Mohd Harfiz, Eraricar Salleh, Siti Nur Hana Mamat, Ida Idayu Muhamad. 2014. Starch based Active Packaging Film Reinforced with Empty Fruit Bunch (EFB) Cellulose Nanofiber. Procedia Chemistry, Volume 9, 2014, Pages 23-33

Unmar G. and Mohee R. 2008. Assessing the effect of biodegradable and degradable plastics on the composting of green wastes and compost quality. Review Article Bioresource Technology, Volume 99, Issue 15, October 2008, Pages 6738-6744.

Van Soest, P.J., Robertson,J.B., and Lewis, B.A. 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch- polysaccharides in relation to animal nutrition. Journal of Dairy Science 74:3583-3597

