BIODEGRADATION OF VARIOUS OIL PALM FIBRE WASTE VIA VERMICOMPOSTING

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BIODEGRADATION OF VARIOUS OIL PALM FIBRE WASTE VIA VERMICOMPOSTING

by

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LIST OF ABBREVIATIONS AND SYMBOLS

EFB	Empty Fruit Bunch
OPT	Oil Palm Trunk
OPF	Oil Palm Frond
POME	Palm Oil Mill Effluent
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosporus
TK	Total Potassium
TCa	Total Calcium
Mg	Magnesium
Mn	Manganese
Zn	Zinc
Ca	Calcium
Fe	Ferum
Cu	Cuprum
N	Nitrogen
P	Phosporus
C	Carbon
K	Potassium
S	Sulfur
H	Hydrogen
O_2	Oksigen
C/N ratio	Carbon over Nitrogen ratio
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CO_2	Carbon Dioxide
NH^+_4	Ammonium
NO^-_3	Nitrate
NaOH	Sodium hydroxide
H_2SO_4	Sulfuric acid
$HClO_4$	Hydrochloric acid
HNO_3	Nitric acid
NO^-_2	Nitrite
N_{org}	Organic nitrogen
MPOB	Malaysian Palm Oil Board
AAS	Atomic Absorption Spectrophotometer
E.fetida	*Eisenia fetida*
E.eugeniae	*Eudrilus eugeniae*
E.andrei	*Eisenia Andrei*
L.Rubellus	*Lumbricuc Rubellus*
SEM	Scanning Electron Microscopy
SE	Standard error
i.e	which is
e.g	Example
^{o}	Degree
℃	Degree celcius

α	Alpha
ß	Beta
%	percentage
<	Less than
>	More than
±	Plus minus
≈	Almost equal to
*	Asterisk
^{2}	Superscript two
^{3}	Superscript three
g	Gram
cm	Centimeter
mL	Milliliter
µm	Micrometer
mg/kg	Milligram per kilogram
meq	Milliequilibrium
nm	Nanometer
mm	Millimeter
ppm	Part per million
kV	Kilovolt
Pa	Pascal
e	Eksponen
R^2	Regression line
wt	Weight
v/v	Volume over volume
w/v	Weight over volume

BIODEGRADASI PELBAGAI JENIS SERAT KELAPA SAWIT DENGAN MENGGUNAKAN CACING SEBAGAI AGEN PEREPUTAN

ABSTRAK

Satu kajian tentang biodegradasi pelbagai jenis sisa kelapa sawit, iaitu tandan kosong kelapa sawit, pelepah kelapa sawit dan batang kelapa sawit telah dijalankan dengan menggunakan cacing Eudrilus Eugeniae (cacing Africa) dan Eisenia Fetida (cacing merah). Berat cacing tanah dan jumlah kokon yang dihasilkan ditimbang dan dikaji setiap minggu. Serat sisa kelapa sawit yang direputkan dengan menggunakan cacing telah dilakukan selama 84 hari dengan suhu kawalan 25 ± 1.0ºC. 5 gram cacing tanah spesies Eudrilus Eugeniae dan Eisenia Fetida telah ditambah ke dalam setiap bekas yang mengandungi 150 gram serat sisa kelapa sawit. Dalam kajian tindak balas cacing tanah terhadap komponen selulosa dan lignin menunjukkan peratusan pereputan selulosa sangat tinggi di dalam tandan kosong kelapa sawit berbanding pelepah kelapa sawit dan batang kelapa sawit. Manakala, biodegradasi serat kelapa sawit tanpa menggunakan cacing tidak menunjukkan pereputan selulosa dan lignin yang tinggi. Disebalik itu, hanya sedikit sahaja berlakunya pereputan terhadap lignin dengan menggunakan cacing di dalam ketiga-tiga serat kelapa sawit. Pereputan menggunakan cacing menunjukkan kadar nitrogen dan fosforus yang tinggi di dalam tandan kosong kelapa sawit malah menurunkan kadar kepekatan logam berat. Mikroskop electron juga menunjukkan berlakunya pereputan pada struktur morfologi sebelum dan selepas biodegradasi dengan menggunakan cacing terhadap tandan kosong kelapa sawit dan pelepah kelapa sawit. Batang kelapa sawit tidak menunjukkan pereputan yang jelas. Data menunjukkan tandan kosong kelapa sawit paling sesuai dijadikan sebagai bahan makanan (subtrat) bagi cacing tanah berbanding pelepah kelapa sawit dan batang kelapa sawit. Kajian yang seterusnya

telah dilakukan dengan menggunakan tandan kosong kelapa sawit dicampur dengan sisa pepejal kelapa sawit dalam pelbagai nisbah dengan membuat perbandingan antara dua spesies cacing tanah, Eudrilus Eugeniae dan Eisenia Fetida. Pertumbuhan dan pembiakan kedua-dua spesies cacing tanah telah dikaji setiap minggu apabila diletakkan di dalam campuran tandan kosong kelapa sawit dan sisa pepejal kelapa sawit. Sifat fizik dan kimia telah dijalankan selama 12 minggu terhadap najis cacing dan sisa air yang telah dihasilkan oleh kedua-dua spesies cacing tersebut. Nilai tertinggi nitrogen telah direkodkan di dalam campuran 50% tandan kosong kelapa sawit + 50% sisa pepejal kelapa sawit. Penurunan C/N dan peningkatan jumlah fosforus, jumpah kalium, jumlah kalsium dan jumlah magnesium juga telah direkodkan. Jumlah kandungan logam berat kelihatan tinggi tetapi masih lagi mengikut ketetapan yang dibenarkan. Secara keseluruhan menunjukkan campuran 50% tandan kosong kelapa sawit + 50% sisa pepejal kelapa sawit sangat sesuai dalam pereputan sisa kelapa sawit dengan menggunakan cacing tanah. Hasil daripada pereputan sisa-sisa kelapa sawit ini akan menghasilkan baja organik yang berkualiti tinggi di samping mengurangkan kos pemprosesan sisa.

BIODEGRADATION OF VARIOUS OIL PALM FIBRE WASTE VIA VERMICOMPOSTING.

ABSTRACT

A study of the biodegradation of various palm oil mill wastes, viz. empty fruit bunch (EFB), oil palm frond (OPF), oil palm trunk (OPT) and palm oil mill effluent (POME) using earthworm species *Eudrilus Eugeniae (E.eugeniae)* and *Eisenia fetida (E.fetida)* was conducted under laboratory conditions. Earthworms were weighed weekly and the numbers of cocoons produced per week were assessed. The oil palm biomass was vermicomposted for 84 days under controlled conditions (25 ± 1ºC). 5 g of clitellated adult worms *E.eugeniae* and *E.fetida* were added to vermicomposter. In the study of the effects of the earthworms' digestability towards the major lignocellulotic component (cellulose and lignin) of the EFB in the vermireactors (EFB WORM), results showed significant degradation rate of the cellulose. A similar trend was also observed for the lignin degradation. Meanwhile, lower percentages of the lignocellulosic degradations were observed for the control reactor (without earthworms). The vermicomposts were rich in nitrogen and phosphorus and had low levels of heavy metals. Scanning Electron Microscopy revealed the morphological structure of the oil palm fibre wastes before and after vermicomposting. The data revealed that vermicomposting (using *E.eugeniae*) is a suitable method for the decomposition of oil palm wastes into value added material, especially for EFB rather than OPT and OPF. The next stage was to determine the growth and reproduction of *E.fetida* and *E.eugeniae* to evaluate their suitability for vermicomposting of EFB when amended with POME. A total of six vermicomposters filled with different ratios of EFB and POME were maintained for this study under laboratory conditions. Physico-chemical properties of both solid (vermicast) and liquid (vermileachate) were monitored for 12 weeks. *E.fetida* appeared as more efficient than *E.eugeniae* in terms of palm oil mill mineralization rate. The growth and cocoon production were also better in *E.fetida* for EFB wastes. Highest value of total kjeldahl nitrogen (TKN) was recorded in 50% EFB + 50% POME (V_6) feed mixture containing vermicomposter. A significant decrease in C/N ratio and increase in total phosporus (TP), total potassium (TK), calcium and magnesium content were recorded. The heavy metal content was higher in vermicompost obtained in all the reactors than in the initial feed substrates. Overall, V_6 vermibed appeared as an ideal substrate to manage oil palm industrial waste effectively. Vermicomposting can be proposed as a low-input basis technology to convert industrial waste into value-added biofertilizer.

CHAPTER 1

INTRODUCTION

1.1 General

Oil palm is the main agricultural crop in Malaysia with the total planted area recorded in 2009 at 4.69 million hectares, and based on the distribution rate of biomass per hectare that has been formulated by Gurmit, (1994) and widely accepted; the total oil palm biomass availability (empty fruit bunch, EFB; oil palm trunk, OPT and oil palm fronds, OPF) was estimated about 65.46 million tonnes (dry weight). Hereby, agro-wastes from the oil palm industry (EFB, OPT and OPF) have attracted attention as potential sources for new value-added materials. Oil palm biomass (EFB, OPT and OPF) is an agricultural by-product periodically left in the field during the replanting, pruning and milling processes. Oil palm biomass are largely unutilized after a 25-year economic life of the tree and causes severe environmental pollution problems (Abdul Khalil *et al.,* 2001; Sreekala *et al.,* 2002). Oil palm wastes is a suitable raw material for recycling because it is produced in large quantities in mill areas especially EFB.

A palm oil mill generates large volumes of palm oil mill effluent (POME), estimated around 0.7 tonne per tonne fresh fruit bunch (FFB) processed. In general, the palm oil milling process can be categorized into a dry and a wet (standard) process. The wet process of palm oil milling is the most common and typical way of extracting palm oil, especially in Malaysia. For each tonne of crude palm oil produced, it is estimated that 5.0–7.5 tonnes of water are required, and more than 50% of this water ends up as palm oil mill effluent (POME) (Ahmad *et al.,* 2003). Some environmental problems are considered too caused by high biochemical oxygen demand (BOD) (25,000 mg/L), chemical oxygen demand (COD) (53,630mg/L), oil and grease (8370 mg/L), total solids (43,635 mg/L) and suspended solids (19,020mg/L) if the untreated effluent is discharged into watercourses (Ma, 2009). Besides, POME also contains appreciable amounts of nitrogen (N), phosporus (P), potassium (K), magnesium (Mg) and calcium (Ca) which are essential nutrient elements for plant growth.

Lignocellulosic materials are the most abundant polymer in nature and constitutes to a large carbon pool for microorganisms, the main agents responsible for soil organic matter decomposition. Cellulolysis occurs as the result of the combined action of fungi and bacteria towards the lignocellulosic materials during composting. There are several factors that limit the degradation of cellulose in soils, which make the process slow. These factors also influence the activities of the cellulases, such as concentration, location, and the mobility of the enzymes (Sinsabaugh & Linkins, 1988). Moreover, the production of cellulases is regulated by the speed of accumulation of enzyme products during the process. According to Lynd *et al.*, (2002), hemicellulose and lignin content, as well as the degree of the cellulose crystalline can also determine the rate at which the cellulose is metabolized.

Some problems and challenges are faced by oil palm industry in exploiting the waste products, but in the recent development, this oil palm biomass have been exploited for the wood based products (Nor Yuziah & Paridah, 2008) ; bioenergy (Sansubari, 2008); and for bio-fertilizer (Khalid & Tarmizi, 2008). At controlled rates, the land applications have been shown to give positive responses to oil palm yields and negligible pollution to the environment (Tam *et al.,* 1982; Lim *et al.,* 1991; Mohd Hashim, 1991; Lim & Chan, 1993). The traditional disposal methods such as open dumping and land filling practices of these materials are not only increasingly expensive, but impractical as open space becomes limited. Therefore, there is a need of such ecologically sound technologies which are not only cost effective, but also sustainable in terms of possible recovery of recyclable constituents from effluents as they are rich in nutrients and have higher organic matter content.

In recent years, the industrial waste management is using vermicomposting (Elvira *et al.,* 1997). Vermicomposting is stabilization of organic material involving the joint action of earthworms and microorganisms. According to Vinceslas-Akpa & Loquest, (1997) and Suthar (2007a), earthworm accelerates the transformation of organic waste material into more stabilized forms by aeration and bioturvation, either by their excreta and qualitative or quantitative influence upon the telluric microflora. Vermicomposting with earthworms often produces a product with a lower processing time, lower mass, phytotoxicity is less likely, an additional product (earthworms) produced, greater fertilizer value, and more N released (Lorimor *et al.,* 2001).

The transformation of wastewater sludge into vermicompost is of double interest: on the one hand a waste is converted into value added product, and on the other, it minimizes a pollutant that is a result of increasing industrialization. Elvira *et al.* (1998) have reported that vermicomposting of paper mill sludge was using *Eisenia*

Andrei (*E.andrei*) under laboratory as well as field conditions. Nogales *et al.* (2005) then reported that the vermicomposting of winery waste was using *E.andrei* under laboratory conditions. Studies have revealed that vermicomposting could be an appropriate technology to transfer organic wastes to value-added products, which is vermicompost (Kale, 1998).

1.2 Objectives of the study:

1) To determine the degradability of lignocellulosic components of oil palm biomass fibres during vermicomposting.

2) To determine the suitability of EFB amended with POME sludge cake for vermiculture of *Eudrilus Eugeniae* and *Eisenia Fetida*.

3) To evaluate nutrients quality of various mixtures of EFB and POME sludge cake.

4) To analyse leachate from vermicomposting of EFB amended with POME sludge cake.

CHAPTER 2

LITERATURE REVIEW

2.1 Biomass production and its uses in the oil palm industry

Oil palm is one of the most versatile crops where nearly every part of the palm, from oil to the entire biomass can be utilized. There is a need to look beyond crude palm oil (CPO) as the sole source of revenue, especially utilization of biomass, in order to optimize total returns. Through intensive research and development efforts, large quantities of oil palm biomass from the Malaysian oil palm industry have now found applications in several commercially viable bio-based products in country. The most important is the utilization of the ligno-cellulosic materials from the biomass for a number of value-added products through physical, biological, and chemical innovations (Chan, 2009).

Since the establishment of the oil palm, cocoa and rubber plantations, the biomass from these crops was used as a mulching material when practicing ‘green’ agriculture (Chan, 1999). This would mean that their management practices would include planting of tree crops, ground legume covers, using of trunk and frond biomass as chips and mulch during replanting, planting on conservation terraces and using of silt pits to conserve soil, nutrient and moisture. Such green practices have since been expanded to include the utilization and recycling of mill biomass residues on land as well as their use for manufacturing of non-wood products and for steam power generation (Yusof & Chan, 2003). Through the practice of zero burning of plant residues of the former stand at replanting, the plantation industry has consciously been using the biomass in a balanced manner in the field to maintain organic matter and soil fertility and also to provide fibre for substitution of timber trees.

Oil palm biomass of empty fruit bunches, fronds, trunk, fibre, shell and effluent are obtained under two situations in the field and in the mill. Firstly, during productive life of the palm covering about 25 years, the two common co-products are fresh fruit bunches (FFB) and pruned fronds from oil palm growing in the plantations and also the additional trunk biomass during replanting. Secondly, during processing of FFB in the mill, the four common co-products biomass materials are the empty fruit bunches fibre, shell and effluent from the mills, despite of the palm oil, kernel oil and meal (Chan, 2009).

2.2 Distribution of Oil Palm Planted Area

Malaysia is the top producer of palm oil in the world and at present, the total area under oil palm cultivation is about 4.48 million hectares, with the total palm oil production at 26.47 million tonnes (MPOB, 2008). Table 2.1 shows the distribution of oil palm planted area in Malaysia in year 2008. The total area under oil palm cultivation in Peninsular Malaysia was 2.4 million hectares or 53% of the total area, while Sabah and Sarawak was about 2.08 million hectares or 46.4% of the total area. However, Sabah shows the largest planted area at 29.7%, followed by Johor and Pahang at 15.3% and 14.4% respectively. Distribution of the planted area for the mature and immature palms by state is shown in Table 2.2. From the table, it shows that in Peninsular Malaysia, about 2.1 million hectares of plantation are under mature palm (fruit production) which means that it is ready for replanting while about 260 575 hectares are still immature (less than 25 years old) (MPOB, 2008).

Planted area from the private estates is about 59% while for the Government Schemes are about 21%. In the Government Scheme, FELDA contributes the highest planted areas as compared to FELCRA and RISDA. Private estates contributed about 60% of the total planted area in Malaysia while from the Government Scheme; FELDA contributed the highest planted area which is about 16%. Planted area by FELCRA and RISDA is only about 4% and it may be increased in year 2009 (MPOB, 2008).

Table 2.1: Oil palm planted area in Malaysia (2008) (MPOB, 2008)

State	Oil palm planted area (hectares)
Johor	687, 906
Kedah	77, 080
Perlis	251
Kelantan	103, 636
Melaka	48, 408
Negeri Sembilan	171, 647
Pahang	647, 879
Pulau Pinang	13, 001
Perak	363, 022
Selangor	135, 529
Terengganu	161, 660
Peninsular Malaysia	2, 410, 019
Sabah	1, 333, 566
Sarawak	744, 372
Sabah & Sarawak	2, 077, 938
Total, Malaysia	**4, 487, 957**

Table 2.2: Area under oil palm (mature and immature) by states: 2008 (Hectares) (MPOB, 2008)

State	Mature	Immature	Total
Johor	615, 834	72, 072	687, 906
Kedah	73, 057	4023	77, 080
Kelantan	82, 771	20, 865	103, 636
Melaka	45, 047	3, 361	48, 408
N.Sembilan	153, 940	17, 707	171, 647
Pahang	568, 937	78, 942	647, 879
P.Pinang	12, 711	290	13, 001
Perak	330, 938	32, 084	363, 022
Perlis	232	19	251
Selangor	126, 235	9, 294	135, 529
Terengganu	139, 742	21, 918	161, 660
P.Malaysia	2, 149, 444	260, 575	2, 410, 019
Sabah	1, 197, 284	136, 282	1, 333, 566
Sarawak	569, 196	175, 176	744, 372
Sabah/Sarawak	1, 766, 480	311, 458	2, 077, 938
MALAYSIA	**3, 915, 924**	**572, 033**	**4, 487, 957**

2.3 Availability of Oil Palm Biomass

Besides the oil, the oil palm industry also generates massive quantities of oil palm biomass such as empty fruit bunches (EFB), fronds (OPF), and trunks (OPT) as shown in Figure 2.1 (a, b and c). The biomass is available from the replanting and through routine field and mill operations. Generally, OPF are pruned from each matured oil palm tree per year during the harvesting of fresh fruit bunches (FFB) in the field (Anis *et al.,* 2008). For processing, the FFB are then collected and transported to the palm oil mills. Next, at the palm oil mill, the sterilized fresh fruit bunches go through a threshing process to separate the fruit nuts from the empty fruit bunches.

a) Empty fruit bunch (EFB)

b) Oil palm frond (OPF)

c) Oil palm trunk (OPT)

Figure 2.1(a, b and c): Sources of oil palm biomass

Studies showed that the empty fruit bunch consists of around 75-80% of spikelets and 20-25% of stalk (Kamarudin *et al.,* 1996). The oil palm fronds are collected during pruning and replanting activities. The collected fronds during the pruning activity currently give an average of 43.12 million tonnes (wet basis) in Peninsular Malaysia and 32.7 million tonnes (wet basis) in Sabah and Sarawak. It is estimated that more than 70 thousands hectares of oil palm will be due for replanting every year. This would involve the felling of approximately 9 million palms.

About 53.9% (dry weight) of fibre bundle can be extracted from a trunk; with the remaining parts are followed by parenchyma tissues (31.7%) and the bark which contribute 14.5% (dry weight) of the trunk respectively. Hence the amount of oil palm biomass (wet weight) available annually is estimated to be from OPF, 75.90 million tonnes from the field, EFB about 16.05 million tonnes from the mills, and OPT about 13.92 million tonnes or 21.63 million cubic meters from replanting (Table 2.3) (Anis *et al.,* 2008). Thus the quantities at hand could make a very substantial contribution to the production of palm-based composites for a wide range of applications without depleting the nations' fibre resources from the natural forest and forest plantations. The amounts of oil palm biomass by states are shown in Table 2.4 where Sabah shows the highest amount.

Table 2.3: The amounts of oil palm biomass (wet weight) (Anis *et al.,* 2008)

Sources of oil palm biomass	Unit	
	Million tonnes per year (wet weight)	Million cubic meter per year
Peninsular Malaysia		
1. Oil palm trunk (OPT)	7.91	12.29
2. Oil palm frond (OPF)	43.12	
3. Empty fruit bunch (EFB)	9.69	
Sabah and Sarawak		
1. Oil palm trunk (OPT)	6.01	9.34
2. Oil palm frond (OPF)	32.78	
3. Empty fruit bunch (EFB)	6.36	
TOTAL	**105.87**	**21.63**

Table 2.4: Availability of oil palm biomass by states (tonnes/year; dry weight) (Anis *et al.,* 2008)

State	Empty fruit Bunch	Prunes oil palm fronds	Felled oil palm trunks	Total
Pahang	626 141	1 452 059	526 191	2 604 391
Terengganu	160 865	367 948	100 236	629 049
Kelantan	83 257	190 441	54 413	328 111
Johor	772 740	1 536 120	588 887	2 897 747
Selangor	237 647	442 027	98 585	778 259
N.Sembilan	181 040	336 780	100 919	618 739
Melaka	45 050	83 802	5841	134 693
Kedah	49 451	103 355	14 405	167 211
P.Pinang	19 153	39 980	8081	67 214
Perak	421 415	765 462	362 735	1 549 612
Sabah	943 401	2 017 747	548 386	3 509 534
Sarawak	154 845	350 873	129 580	635 298
TOTAL	**3 695 005**	**7 686 594**	**2 538 259**	**13 919 858**

2.4 Cell wall components

Plants are made up of individual cell which contain a cell wall, the morphology of the plant such as a structural support, and control the passage of water and nutrients (Schuerch, 1963). Plant cell wall contains of skeletal polysaccharides, hemicelluloses, polyuronides, lignin and proteins. The chief components of woody plant cell walls are cellulose, hemicelluloses, and lignin.

2.5.1 Cellulose

Cellulose is the most abundant organic material on earth, containing approximately 50% of all biomass for an annual production of about 100 billion tonnes. Preston, (1974) stated that it is a long chain polymer of ß-D-glucose in the pyranose form (Figure 2.2), linked together by 1,4 –glycosidic bonds to form cellobiose residues (Figure 2.3) which are the repeating units in the cellulose chain. The ß-linkage requires that the alternate glucose units must be rotated through 180º. An important implication of this structure is a marked tendency for the individual cellulose chains to come together to form bundles or by hydrogen bonds which held the crystalline order together. A major factor in the high stability of cellulose is the conformation of the pyranose rings, where the total energy lies close to the minimum.

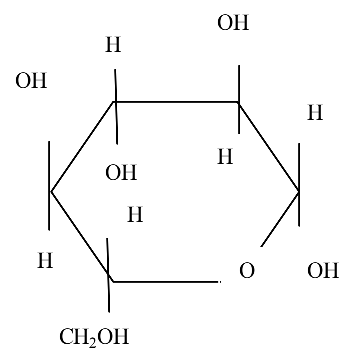

Figure 2.2: ß-D-gluco-pyranose (Immergut, 1963)

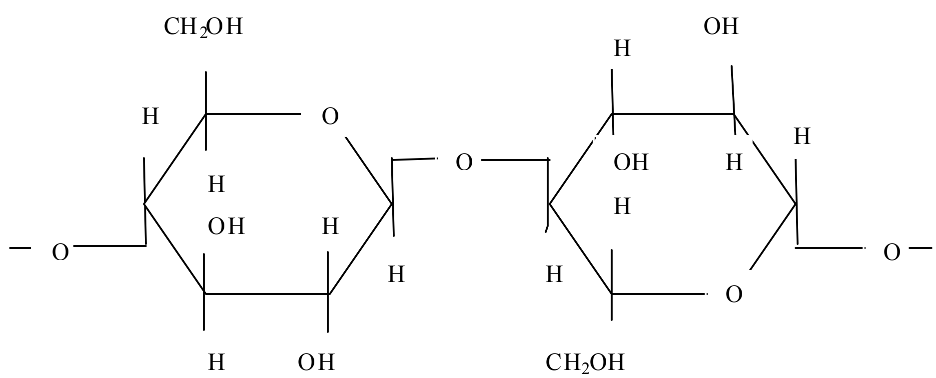

Figure 2.3: Cellobiose residue (Immergut, 1963)

Biodegradation of cellulose wastes by bacterial or fungal enzymatic activities represents a large area of research experiments concerning the influence of different biochemical and physical factors, where it interferes in cellular dynamics of such biotechnological processes (Verstraete, 1992). The cellulose biodegradation using bacterial and fungal cells immobilized in polymerized hydrogels is essentially based on the complex interactions between biotic factors, in first place, including: cell age, morphogenetic specificity of microorganisms, and cell wall composition. In addition, the cellulose composition, especially its complexity with hemicellulose and lignin, as well as the abiotic ones, such as: physico-chemical surface properties of polymerized hydrogels which will be used as immobilization matrices, their pH value, porosity, and ionic strength of nutritive solutions added to substrata (Lowenfels & Lewis, 2006).

2.5.2 Hemicelluloses

In nature, the major part of biomass is lignocellulose and, consequently, its degradation is essential for the operation of the global carbon cycle. Lignocellulose, such as wood, is mainly composed of a mixture of cellulose, hemicellulose, and lignin (Sjostrom, 1993). Closely associated with the skeletal polysaccharide cellulose in the cell wall are hemicelluloses, the other structural polysaccharides. The different between hemicelluloses with other cellulose is although hemicelluloses are water insoluble, but they can be dissolved in strong alkali. This characteristic of hemicellulose may be used to separate the hemicelluloses from the total carbohydrate fraction called holocelluloses, leaving essentially pure or α–cellulose behind.

Another property of hemicelluloses is they are more readily hydrolyzed by acid compared to cellulose (Schuerch, 1963).

Basically, there are only a few hemicellulose structures found in all plants, which shows small modifications within the same plant in different tissues, and so with the modification in different plants. In softwoods which contain about 25% hemicelluloses, mannose, galactose, xylose, glucose and arabinose are the principal constituent sugars in decreasing abundance (Preston, 1974). Meanwhile, in hardwoods which contain about 30% hemicelluloses, xylose, galactose, and mannose are the principal constituents' sugars in decreasing abundance, with minor amounts of rhamnose and arabinose. Both types contain 4-O-methylglucuronic acid. Generally, pentosans are rich in annual plants and hardwoods while in softwoods, the hexosans predominate.

2.5.3 Lignin

The remaining 25% of the cell wall material in wood plants is lignin, the third major of cell wall component. In fact, lignin which is woody is the necessary component for plant. Lignin serves as cement between the wood fibre, as a stiffening agent within the fibre, and as barrier to enzymatic degradation of the cell wall. According to Sarkanen & Ludwig (1971), most bacteria reach their limit when it comes to the noncarbohydrate lignin, another prevalent, molecularly complex plant material. Lignin is a much more complex organic molecule than cellulose; these are resistant to the enzymes produced by most bacteria and are left for fungi to decay.

In the production of chemical wood pulps, various chemical processes are techniques used for lignin to dissolve away. Preston (1974) reported that despite of their importance and tremendous natural abundance, second only to cell wall carbohydrates, lignin resisted structural characterization until quite recently and still poses a major problem for their utilization. The lignin from grasses, softwoods, and hardwoods differ in their composition, chiefly in methoxyl substitution and the degree of carbon-carbon linkage between phenyl groups. However, their common structural features predominate, and the conifer lignin schematic structure (Freudenberg & Harkin, 1964) shows the features important for conversion into chemicals.

The macromolecular properties and structural characteristics of lignin make biodegradation studies uneasy. Suitable model compounds of lignin are difficult to obtain and for biodegradation studies, there are only a few assays which are suitable (Buswell & Odier, 1987). The methods used for isolating lignin can be classified into two methods which are removed and recovered selective lignin from the final solution, and the other one is lignin is left as an insoluble residue following dissolution of the carbohydrates. Determination of Kappa number and Klason lignin are the most common methods used to analyse lignin quantitatively. Kappa number is an important parameter in the pulp and paper industry and basically, it is determined by oxidized the lignin selectively from pulp using a potassium permanganate solution (Argyropoulos & Menachem, 1997). By using gravimetric technique, Klason lignin is determine after extracting the sample with sulphuric acid to dissolve out the other components (Dence, 1992).

2.5.4 Extractives

According to Buchanan (1963) and Hillis (1962), extractive is the term applied to the extraneous plant components that may be separated from the insoluble cell wall material by their solubility in water or organic solvents. They include many different kinds of chemicals and a large number of individual compounds. Traditional uses of chemicals from biomass have involved such extractives components as tall oil fatty acids, rosin, turpentine, tanning materials, rubber, volatile oils, gums and camphor. Classification of extractives is made difficult by their great variety. Different structures contain different extractives even they are within the same plant (Preston, 1974). There are several major categories of extractives which are volatile oils, terpenes (turpentines, tropolones, cymene, resin acids, and sterols), fatty acids, unsaponifiables, polyhydric alcohols, nitrogen compounds, and aromatic compounds (acids, aldehydes, alcohols, phenylpropane dimmers, stilbenes, flavonoids, tannins, and quinones) (Hillis, 1962).

2.5 The role of earthworms in organic waste.

Darwin (1881) highlighted the breakdown of organic debris of earthworms on the soil surface and in the soil turnover. Since then, it has taken almost a century to appreciate their important contribution in curbing organic pollution and providing topsoil in impoverished lands. This realization, although late, has awakened the global population to serious thought on utilizing them for ecological benefits.

By the turn of century, earthworms potential as a biological tool should be much better understood to make organic farming and sustainable development a reality with the use of selected species of earthworms. By regulating the moisture levels and mixing the ingredients in proper ratios that can be accepted by the earthworms, coffee pulp (Arellano *et al.*, 1995), sugar factory waste (Kale *et al.,* 1994), and pig solids (Dominguez & Edwards, 1994) could all be converted into good quality soil additives, along with the biomass production of earthworms.

The reports of Vinceslas-Apka & Loquest (1994) and Fredrickson *et al.* (1994) have shown that the involvement of earthworms in the composting process decreases the time of stabilization of the waste and produces an efficient organic pool with energy reserves as vermicompost. Garcia *et al.* (1994) showed in their studies that the sludges from both agri based industries and domestics' sewage plants not accepted as soil additives directly on fields can be a food source for composting earthworms, with suitable organic amendments such as plant litter or animal waste to produce the worm biomass and obtain better quality soil additives.

2.6 Earthworms as biodegraders of waste biomass.

The decline in productivity status of these tropical soils is majorly caused by the loss of topsoil due to practices associated with the indiscriminate use of chemicals. This fact has indeed increase the use of organic wastes on the fields. The availability of cattle dung has declined and the current need is to get the required organic soil additives from unutilized available plant biomass residues in minimum time (Sinha *et* *al.,* 2008). In addition to the old practice of pit composting, various methods have been practicing. Engineering skills are employed to minimize the time of composting and to provide good aeration of composting materials. For composting of lignocellulose-based materials, selected groups of fungi are used in different places (Chaoui *et al.,* 2003).

The diversity and richness of earthworms species is not much less than in temperate regions. However, much of the importance given to earthworms' activity in temperate soils is lacking in tropical regions (Bano & Kale, 1991). The help of earthworms in the breakdown of waste has been broaden by the help of food niches and strategies that have been developed among different species of earthworms. A greater affinity for nitrogen and rich organic matter live in a more unstable environment has been showed by the Epigeic earthworms' species. This Epigeic earthworms' species resemble the spiral stages of ecological development, with a higher metabolic rate, higher fecundity, smaller body size, , and shorter life cycle (Doube & Brown, 1998). In natural conditions, their survival depends on the degree of biotic pressure from predators and the environment. These earthworms come from the components of the tropical forest floor community. They have entered the agricultural plantations with the loss of natural forests, (Edwards, 1998).

The farming community has been neglecting the importance of organic manures and additives due to the higher yields from the use of chemical fertilizers. Farmers have been unaware that in order to restore the cycle of events in the soil to keep it productive, the organic wastes are essential. In recent years, the chemicals applied to the soil has short-circuited this cycle of events and deprived the soil organisms of their energy source to store the health of the soil through their activity (Chaoui *et al.,* 2003). Earthworms are classified as shredders. As they search for food, the leaf litters in the garden and on the lawn are broken down, greatly spreading up the decomposition of plant material, directly and indirectly. Besides that, the bacteria and fungi have been given better access to the cellulose (and other carbohydrates) and lignin (a noncarbohydrate) in the organic matter as the earthworms opens up leaves and other organic matter. Thus, it is obvious that earthworm facilitate the recycling of nutrients back to the plants. At the same time, the composition of the food web community may change due to competition for nutrients between earthworm and fungi and bacteria. They also even eat the populations of fungi and bacteria (Lowenfels & Lewis, 2006).

The magnitude of the impact of earthworms is shown by the simple fact: leaves on the forest floor or in a garden or lawn only need three months to decay by the help of worm shredding. But, without worm shredding, normally about one or two years are needed. In some parts of the United States and Canada, the earthworms left by fishermen have invaded the forests (Doube & Brown, 1998). These have completely altered the floor habitat. Plus, the entire forests are affected as the litter layer is being decayed far faster than is healthy for the trees and the rest of the soil food web. The minute particles of organic litter that microorganisms can eat are the end results of worm shredding and digestion. Microbial populations in the soil are also enhanced. This is caused by some microbes that are mixed into worm fecal pellets during their formation and elimination, creating protected enclaves of fungi and bacteria (Lowenfels & Lewis, 2006).

2.7 Breakdown of sewage wastes by earthworms

In the late 1970s at the State University of New York (SUNY), the research into the potential use of earthworms to break down and manage sewage sludge is begun (Hartenstein, 1978). It was demonstrated quite early on a laboratory scale that aerobic sewage sludge can be ingested by the earthworm *E.fetida* and egested as casts, and in the process the sludge is decomposed and stabilized (i.e., rendered innocuous) about three times as fast as non-ingested sludge, apparently because of the increases in rates of microbial decomposition in the casts (Edwards, 1995).

During this process, relative to non-earthworm ingested sludge, objectionable odors disappear quickly and there is a marked reduction in populations of the pathogenic microorganisms *Escherichia coli*, *Salmonella entriditis*, and other *Enterobacteriaceae* (Edwards, 1988). Although most of the sludge produced in sewage plants are anaerobic, and when fresh can be toxic to *E.fetida*, after becoming aerobic it becomes readily acceptable to this species. According to Edwards, (1998) mixing other materials, e.g., paper pulp sludge, garden wastes, or other lignin-rich wastes with sewage sludge and composting the mixture using earthworms can accelerate their decomposition. This is due to maceration and mixing of such materials during passage into earthworm casts and passage through the earthworm gut.