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(Research Article)

Processing of Baglog waste left over from oyster mushroom cultivation; case studies

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Abstract

Waste is an issue that must be addressed immediately, waste that is a problem today comes from increasing human activity as an effort to fulfill life. Baglog waste in Limau Manis Sejahtera (LMS) Micro Business has been processed into organic fertilizer, but the processing has not brought high value added, so other innovations are needed. Industrial process activities that aim to reduce, reuse, recycle, and recover agricultural waste by converting it into other products are called valorization. This process converts waste into more valuable products using environmentally friendly process technology by reducing waste and maximizing product utility so as to protect the environment. A biorefinery is an activity that integrates biomass conversion processes to produce fuel, electrical energy and chemicals simultaneously.

Keywords: LMS; Waste; Baglog; Lignocellulose; Innovation

1. Introduction

Waste is a problem that must be addressed right now because human activities are increasing in an effort to fulfill life [1]. Various wastes are produced by human activity conveyance, such as organic waste or trash from food waste, agro-industrial process leftovers, urban sludge, and livestock manure. Despite being organic waste, the garbage nevertheless pollutes the environment, harms human health, and causes other issues. Recycling helps to stop this by adding value to waste, creating new revenue, and forming a portion of the circular bioeconomy.

Actually, by preserving soil fertility, it is advised as a means of addressing global issues or difficulties like climate change, carbon sequestration (C), and food security. But despite this, different efforts still need to take into account different benefits and drawbacks [1]. Mushroom cultivation is one form of organic waste, which is becoming more and more common in Indonesia. The sawdust waste, or "baglog," is used as a growing substrate in the mushroom agro-industry. This endeavor is an attempt to protect the environment. Nonetheless, it is also inextricably linked to the trash generated during cultivation and the post-harvest procedure. The garbage generated consists of contaminated and outdated baglog.

Limau Manis Sejahtera (LMS) Micro Business, situated in Limau Manis Village, is one of the companies in Padang City. The socioeconomic life of the village is influenced by Limau Manis Village's topography, where agricultural areas predominate in terms of land availability and use (fields, rice fields). One of the localities in Padang City where residents cultivate oyster mushrooms is Limau Manis Village.

As far as we know, white oyster mushrooms which are classified as *Pleurotus* in the botanical world. Shimeji mushrooms are another name for oyster mushrooms (*Pleurotus ostreatus*), sometimes referred to as white mushrooms in Japan. The spores on this oyster mushroom have no color, therefore it is completely white. The adult mushroom hood has a

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smooth, somewhat oily surface and is 3 to 8 cm in diameter. Wet circumstances cause the edges to wave. Among the various varieties of oyster mushrooms, white oyster mushrooms are the most extensively grown, well-liked, and commercialized in Indonesia [2].

This business group (LSM) has 40 oyster mushroom cultivators, and an average group of cultivators has 2000–3000 baglog for a single cultivation process, according to an interview (Elma, 2022) with the group leader. The productive life of this baglog is roughly three to four months. In other words, the LMS will produce 40 tons of baglog trash in 3–4 months if this planting medium stops producing. It can produce up to 1 ton of garbage per group member.

The quality of the environment will undoubtedly be impacted by a large-scale decay process if this garbage is not managed appropriately and if it builds up for too long. In addition, it affects the culture of mushrooms because wild mushrooms, which frequently arise on mounds of baglog waste, are a source of toxins that lead to the failure of mushroom cultivation.

Compost, an organic fertilizer made from baglog waste, is the result of LMS's processing (Elma, 2022). Reducing waste volume, air pollution, needing less land for landfills, having a higher market value, providing nutrients for plants, improving soil structure, increasing cation exchange capacity, improving soil water retention, boosting soil biological activity, and raising pH in acidic soils are just a few of the benefits of turning baglog waste into compost.

The purpose of this paper is to offer a response, either in the form of recommendations or other innovations, for the advancement of baglog waste management at LMS specifically and/or for Padang City's mushroom growers. The reaction is based on what was seen at LMS during baglog waste processing operations.

2. Methodology

2.1. Sources of Information

2.1.1. Literature Study

Literature studies were also carried out in this *mini research* activity as an effort to find various information related to organic waste management, especially baglog waste from the rest of oyster mushroom cultivation.

2.1.2. Field Study/Survey

Field studies were conducted through interviews with the head of the LMS group, as well as being directly involved in various similar activities.

2.1.3. Direct explanation

The explanation was given directly by the LMS group leader

2.2. Review Analysis

The analysis method used is SWOT analysis (Strengths-Weaknesses as internal and Opportunities-Threats as external). The most used analysis technique is SWOT analysis. The LMS's SWOT analysis was put together in an attempt to methodically pinpoint issues for strategy development. SWOT analysis is a well-known tool for evaluating the strengths and weaknesses of resources held, as well as external possibilities and challenges. [3]. Alternatively put, SWOT analysis contrasts external and internal forces. Whereas external factors originate from opportunities and threats, internal elements take the form of strengths and weaknesses in its implementation.

2.2.1. SWOT Analysis Matrix

Strategies in SWOT analysis [3]:

- SO strategy

Using strategy, one can leverage their strengths to seize opportunities.

- ST strategy

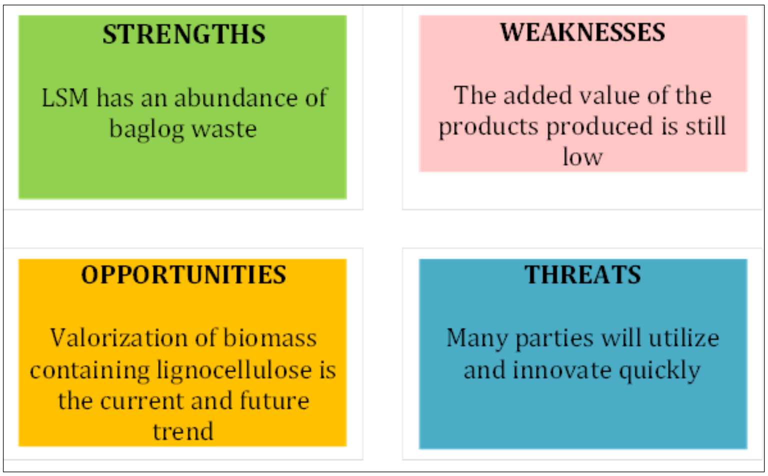
Using strategy, one can lessen or prevent hazards by utilizing strength (Strength).

- WO strategy

A plan to minimize vulnerabilities (Weakness) by seizing possibilities (Opportunity).

- WT strategy

A plan to lessen vulnerabilities (Weakness) and defeat dangers (Threat).



STRENGTHS

LSM has an abundance of baglog waste

WEAKNESSES

The added value of the products produced is still low

OPPORTUNITIES

Valorization of biomass containing lignocellulose is the current and future trend

THREATS

Many parties will utilize and innovate quickly

Figure 1 SWOT Analysis Matrix LMS

3. Baglog Waste Processing by LMS

The technological touch provided will be able to increase the added value of the baglog waste produced so that it can improve the economy of LMS, in addition to environmental quality can also be improved through zero waste activities in mushroom agroindustry activities. Elma (2022) said that LMS in its business not only markets oyster mushrooms but also provides mushroom oyster baglog that have been sown with mushroom seeds with mycelium growth of 30% to 65%. The quantity of baglogs produced as a medium for oyster mushroom development determines how much baglog garbage they generate. When oyster mushrooms reach the end of their harvest season, they can be grown on baglog waste, which is made up of contaminated and old baglog. Figure 2. The condition of the LMS barn (cultivation site), and Figure 3. Is the condition of baglog waste if no processing is done.

Figure 2 Barn (Cultivation Site) LSM [2]

Figure 3 The Condition of Baglog Waste if no Processing [2].

One benefit of using oyster mushroom baglog trash is that it lessens the pollution's negative effects on the environment. In addition to harming the environment, oyster mushroom baglog waste also affects the cultivation of mushrooms because wild mushrooms, which frequently grow in baglog waste mounds, are a source of pollution that makes oyster mushroom cultivation unsuccessful. These fungi release billions of spores that, if carried by the wind or through workers' clothing and limbs, will spread to every corner of the room, including mushroom inoculation.

In order to address these environmental issues, LMS turns baglog into compost. converting garbage baglog into compost with readily accessible equipment and ingredients like EM4, rice bran, cow dung, and husk ash. The value of mushroom baglog may rise due to the resulting compost. The LMS group may choose to use the compost internally or sell it. Compost generated from oyster mushroom baglog waste is combined with other organic ingredients, such as EM4, to create a valuable plant fertilizer. The waste that is created from the mushroom medium is essentially organic compost that has gone through a decomposition process, meaning that turning this waste into ready-to-use organic fertilizer doesn't take a long time [2]. Some documentation of composting done by LMS is presented in Figure 4.

Figure 4 Baglog Composting Processing by LMS [2]

4. Discussion

4.1. Agricultural Waste and its Components

Global waste creation from agricultural products and practices is increasing, leading to environmental stockpiling [4]. Among other things, the rational use of biomass resources necessitates a biorefinery system that can provide many products. For instance, Brazil is paying close attention to the manufacturing of biofuel from agricultural wastes since agricultural residues are readily available, the fuel is environmentally beneficial, and it may promote rural development [5].

Proximate composition, ultimate, lignocellulose, and biochemical analysis make up the majority of biomass composition. Furthermore, several biomass conversion routes are impacted by the energy, metal, and mineral contents of biomass. Moisture, ash, volatile solids, and fixed carbon make up the approximate composition. Low moisture and ash concentration in the feedstock is necessary for thermochemical conversion [6]. Creating valuable products out of agricultural waste appears to be the most cost-effective, sustainable, and ecologically friendly method of waste management. A clean environment, socioeconomic growth, resource conservation and recovery, energy security, and a circular economy are all aided by the value-adding of agricultural waste as a waste conversion and recycling method. Offcuts, crop residues, industrial processing waste, livestock waste, and food waste are the several types of agricultural waste [7]. The main classifications and examples of agricultural waste are shown in Figure 5.

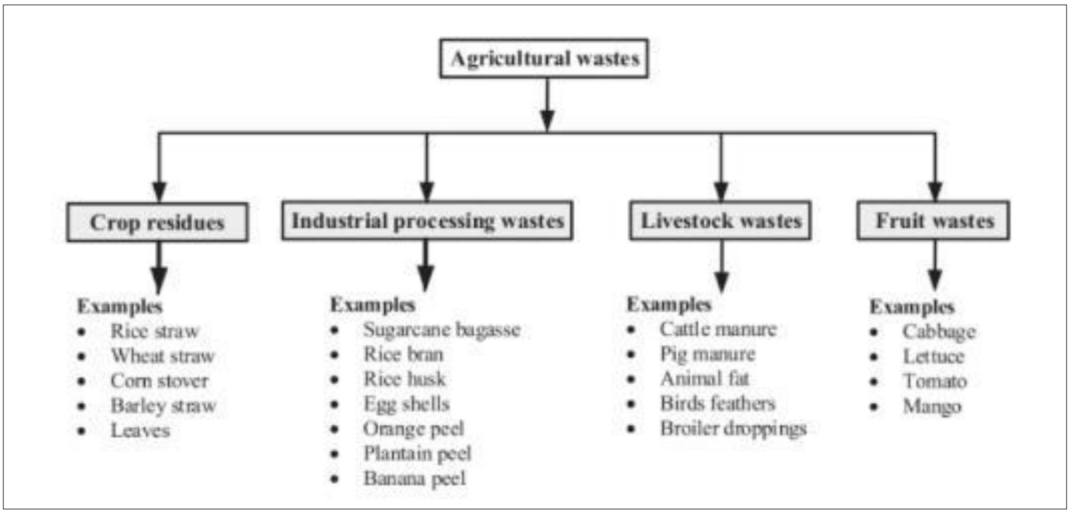


Figure 5 Classification and Main Examples of Agricultural Waste [7]

About 80–85% of agricultural leftovers are made up of lignocellulose, which includes cellulose, hemicellulose, and lignin. The formation of bio-alcohol is caused by the greater amount of cellulose and hemicellulose. 30%–50% cellulose and 20%–38% hemicellulose has found in crop residues. Crops range in lignin concentration from 7% to 21%. Depending on the various sources, agricultural processing waste can contain a wide range of cellulose (21%–45%), hemicellulose (15%–33%), and lignin (5%–24%). Waste rice bran has been demonstrated to be a viable feedstock for the synthesis of bioethanol despite having a low lignin content of 5%. But before ethanol can be produced, bagasse with a high lignin content must be processed to remove the lignin [6].

Unprecedented prospects to manufacture chemicals, fuels, and renewable materials to replace derivatives derived from fossil fuels are presented by lignocellulosic biomass [8], [9]. Direct use of lignocellulosic biomass as a main fuel for combustion and the production of heat and power is possible. Additionally, it can be processed to create several biofuels, including biodiesel, bioethanol, biogas, and biohydrogen. The term "lignocellulosic biomass" refers to a number of different categories that include whole plants (such as aquatic plants, perennial grasses, and energy crops), agricultural residues (such as leaves, stover, straw, husks, pods, seeds, bagasse, roots, cobs, and seed pods), agro-industrial wastes (such as solid cow dung, apple pomace, and citrous peels from cider and other food processing units), forest biomass (such as softwood and hardwood), forest wastes (such as wood chips, slash, dead tree branches and forest thinning, sawdust, and pruning residues), industrial wastes (such as chemical pulp and primary wastewater solids), and municipal solid wastes (such as food wastes, newspapers, kraft paper, and separated garbage) [6]. In this context, lignocellulosic biomass utilization as a plentiful renewable energy source (200 billion tons/year) has drawn a lot of attention [10].

Large amounts of lignocellulose (hemicellulose and lignin) are constantly created by photosynthetic plants and microorganisms. From the forest to the sea, lignocellulose is found in a great variety. The cellulose can be converted to glucose with the aid of the enzyme cellulase, which is then utilized in the feed and food industries. Additional *Poaceae* plants, including elephant grass, switchgrass, and Napier grass, are effective feedstocks for the synthesis of biofuels. Energy can be produced from waste age, animal and poultry manure, and municipal solid trash. For the agro-industry, agricultural crop leftovers such bagasse, leaves, husks, stalks, stems, hulls, husks, stalks, pulp, shells, and straw are excellent feedstocks. Remaining forest materials, such as wood, pulp, branches, leaves, and old stands, are also used to produce electricity. Wood waste from the sawmill, plywood, and furniture industries, among other wood processing businesses, is a useful raw material for the agro-industries that make biochar and wood chips [11]. The chemical composition of biomass by plant species is shown in Table 1.

Table 1 The Chemical Composition of Biomass by Plant Species

Lignocellulose Biomass	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Sugarcane bagasse*	40	24	25
Sugarcane tops**	43	27	17
Bamboo**	41.8	18	29.3
Spruce wood**	43	29.4	27.6
Beech wood	43	29.4	27.6
Corn straw*	40	25	17
Corn stalks**	50	20	30
Corn stover**	38.4	22.9	20.1
Rice husk**	37.1	29.4	24.1
Rice straw*	35	25	12
Hazelnut shell**	25.2	28.2	42.1
Soy straw*	25	12	18
Grass*	25-40	35-50	10-30
Paper residues*	76	13	11
Corncob*	39	35	15
Corn fiber*	15	35	8
Cotton stem*	31	11	30
Wheat bran*	10-15	35-39	8.3-12.5
Softwood (pine)*	44.6	21.9	27.7
Hardwood* (hybrid poplar)	44.7	18.6	26.4
Wheat chaff*	38	36	16
Wheat straw*	38.2	21.2	23.4
Coconut dreg***	14.8	24	12.4
Coconut dreg waste****	47.18	12.10	10.58

Source: * [12]; ** [13]; *** [14]; **** [15]

Utilizing agricultural leftovers for biofuel, bioenergy, and biochemical synthesis is one of the main areas of current research interest worldwide, among other a lignocellulosic biomass. Plant biomass is estimated to be produced at a rate of 200x109 tons year worldwide, of which 8x109–20x109 tons can be converted into biofuels. An estimated 1.5x1011 tons of agricultural waste are added to the world's lignocellulosic biomass annually [16]. A renewed focus on using lignocellulosic biomass to create biochemicals, bioenergy, and derived fuels has emerged in recent years. Furthermore, the new system of producing ethanol, bioenergy, and biochemicals from lignocellulosic biomass may help to generate new jobs and revenue streams. In this sense, a variety of edible crops, including starchy or sugary crops and edible oils, have been utilized in the past to produce first-generation (1G) biofuels, such as biogas, bioethanol, and biodiesel [13]. The three main structural components of lignocellulosic biomass are cellulose, hemicellulose, and lignin. These elements are in a compact matrix structure, making them difficult for microbes and enzymes to access for hydrolysis and destruction. Consequently, the pretreatment procedure aids in the removal of biomass lignin, the breakdown of hemicellulose, and the enhancement of biomass porosity, all of which contribute to a further rise in surface area and a decrease in the cellulose portion's crystallinity [16]. The lignocellulosic components of agricultural waste are shown in Figure 6.

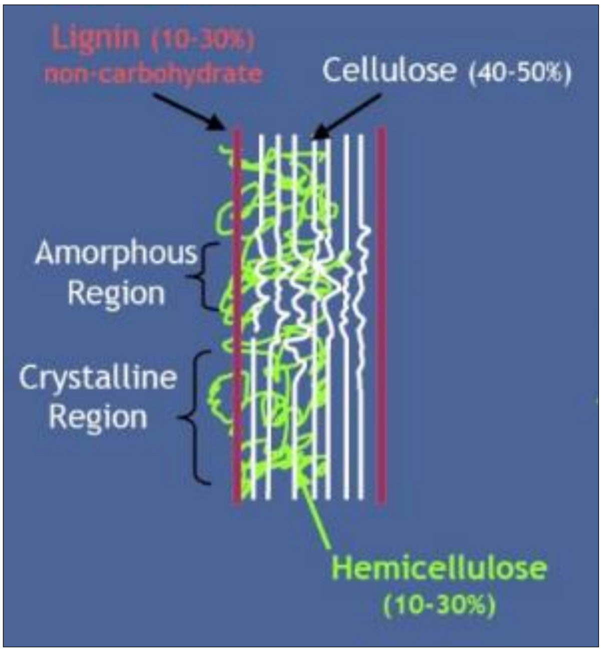


Figure 6 The Lignocellulosic Components of Agricultural Waste [17]

The primary component connecting cellulose and lignin is hemicellulose, a randomly diverse structure of branching polysaccharides found in cellulose. It is made up of arabans, xylans, galactans, and other sugars that are generated by the heterogeneous assembly of sugars like d-xylose, d-mannose, and d-galactose. Hemicelluloses are easily soluble in alkaline, mild acid, and enzymatic media but insoluble in aqueous solution. They are more easily attacked and modified by chemicals and have a lower mechanical strength than cellulose. The amount of hemicellulose in biomass determines how well it can be turned into biofuels [7]. After cellulose, hemicellulose is often the second most prevalent component of biomass. It is a mixture of polysaccharides that includes xylose, arabinose, glucose, galactose, mannose, and other sugars. Xylan, a xylose polymer, is frequently the main hemicellulose in grasses and hardwoods. Therefore, the utilization of significant biomass feedstocks including bagasse, corn stover, Miscanthus, switchgrass, and poplar depends on xylan conversion [18]. D-glucose, D-galactose, D-mannose, D-xylose, L-arabinose, glucuronic acid, and 4-O-methyl-glucuronic acid combine to form hemicellulose, a complex heteropolysaccharide (Figure 7). These polymers are amorphous, have branches that easily interact with cellulose, and are heavily replaced with acetic acid, giving the aggregates flexibility and stability [12].

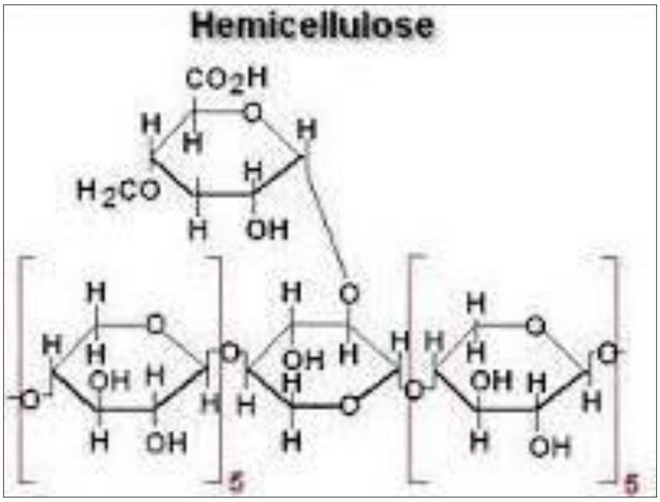


Figure 7 Hemicellulose Structure (https://hasanxch.blogspot.com/2016)

Hemicellulose (C5H4O8) joins cellulose and lignin by wrapping around cellulose fibers. It is made up of a variety of branching polysaccharides. Hemicellulose is structurally made up of monomers such as glucuronic acid, glucose, galactose, mannose, xylose, and arabinose. Hemicellulose is less chemically resistant, amorphous, and readily hydrolyzed by weak acids, bases, and enzymes. Hemicellulose is not as strong physically as cellulose is. Although hemicellulose is less crystalline than cellulose, it is nonetheless utilized to create value-added goods and industrial chemicals [19].

Considered the cell wall of plants, cellulose is the most prevalent naturally occurring linear carbohydrate polymer containing D-glucose. Anhydrous glucopyranose polysaccharide with a characteristic mechanical potential and chemical stability is another way to characterize cellulose. Cellulose has the chemical formula C6H10O5 [7]. The majority of agricultural waste has more cellulose than hemicellulose and lignin combined. A crucial structural element of lignocellulosic biomass is cellulose. In order to preserve the stability of the plant structure, this rigid, fibrous, and impenetrable polysaccharide is structured in the shape of chains within microfibril packs. Cellulose properties dictate the mechanical stability, strength, and chemical fingerprint of biomass [19]. The most abundant naturally occurring polymer in the world is cellulose. Repeating units of -cellobiose, a disaccharide made up of two D-glucose molecules joined by a -1,4 glycosidic link, create the homopolymer. Figure 8 [12].

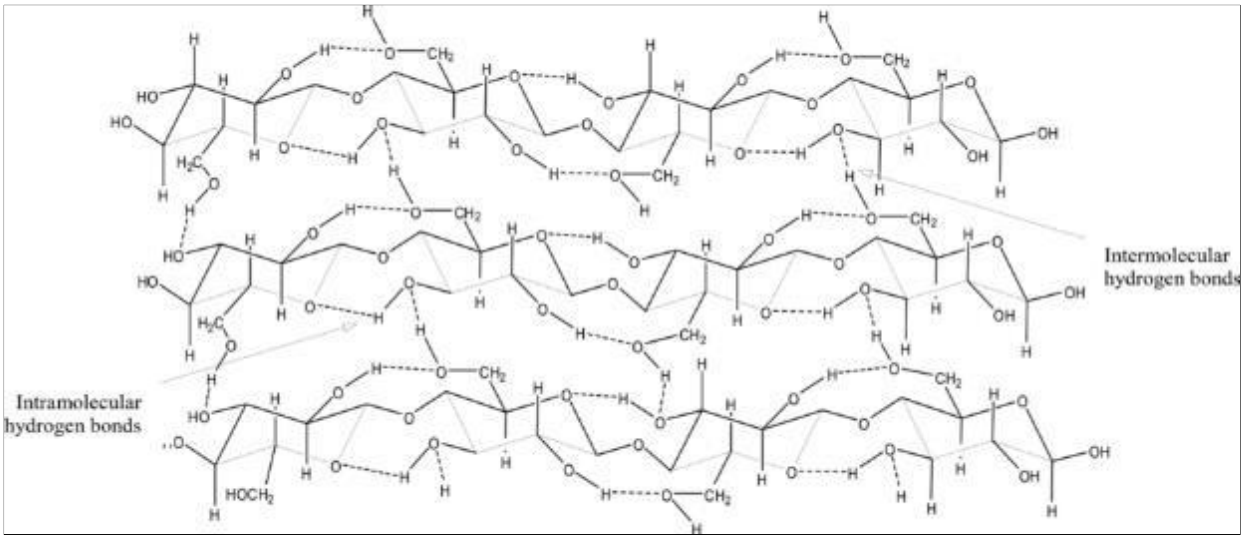


Figure 8 Cellulose Supramolecular Hydrogen Bonds [12]

Plants require lignin, which is second only to cellulose in importance. The water lignin content of woody biomass controls cell wall development, stiffness, resistance to water, and physical, chemical, and microbiological attack. It helps the plant remove water from the soil and gives it the structural support it needs to flourish [7]. The complex aromatic polymer known as lignin is non-carbohydrate and is made up of phenylpropane units arranged unevenly to provide structural stiffness. It strengthens and solidifies the material's cell walls by binding to cellulose and hemicellulose. Additionally, it creates an impenetrable wall that is immune to microbial attack and resistant to both chemical and water resistance. Lignin is water insoluble and aquaphobic. An agricultural waste typically comprises of 35–50% cellulose, 20–35% hemicellulose, and 15–25% lignin. Three distinct phenylpropanoid units make up the amorphous heteropolymer known as lignin: p-cumaryl alcohol, coniferyl alcohol, and sinapyl alcohol (Figure 9). The different types of a biomass have different compositions and structures of lignin components. Coniferyl alcohol and a minor quantity of coumaryl alcohol make up the major structural unit of softwood lignin. Coniferyl and sinapyl alcohols, along with a trace quantity of p-cumaryl alcohol, make up lignin in hardwoods [12]. Lignin has the ability to create unique industrial compounds. The amount of biomass in lignocellulosic materials determines how digestible they are. While materials rich in sugar have high digestibility and short hydraulic retention time, materials heavy in lignin have low digestibility and long hydraulic retention times [19].

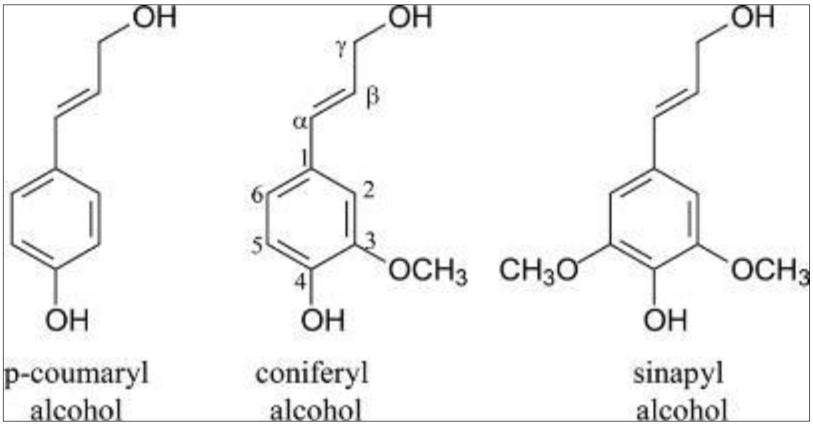


Figure 9 Lignin Primer Precursor [19]

The second most prevalent sugar in lignocellulosic biomass products is xylose [20]; [21]; [22]. Hemicellulose's sugar component, xylose, is the second most prevalent sugar in nature after glucose and can be processed to create goods with significant added value [23]; [12]. Therefore, to achieve the cost-effective bioconversion of lignocellulosic biomass into value-added products, metabolic engineering of fermentation microbes for the efficient and quick utilization of xylose has been carried out [20], [21]. One form of hemicellulose that is common in lignocellulose is xylan, which is primarily made up of pentoses and is the primary hemicellulose found in wood and grass. In the context of biorefineries, research on the transformation of xylan into chemicals, biomaterials, and bioenergy has garnered a lot of attention lately [12]. Several by-products, including arabitol, erythritol, 2,3-butanediol, iso-butanol, citric acid, lactic acid, isoprenoids, carotenoids, fatty alcohols, ethanol, butanol, xylitol, and furfural, can be converted from xylose [23].

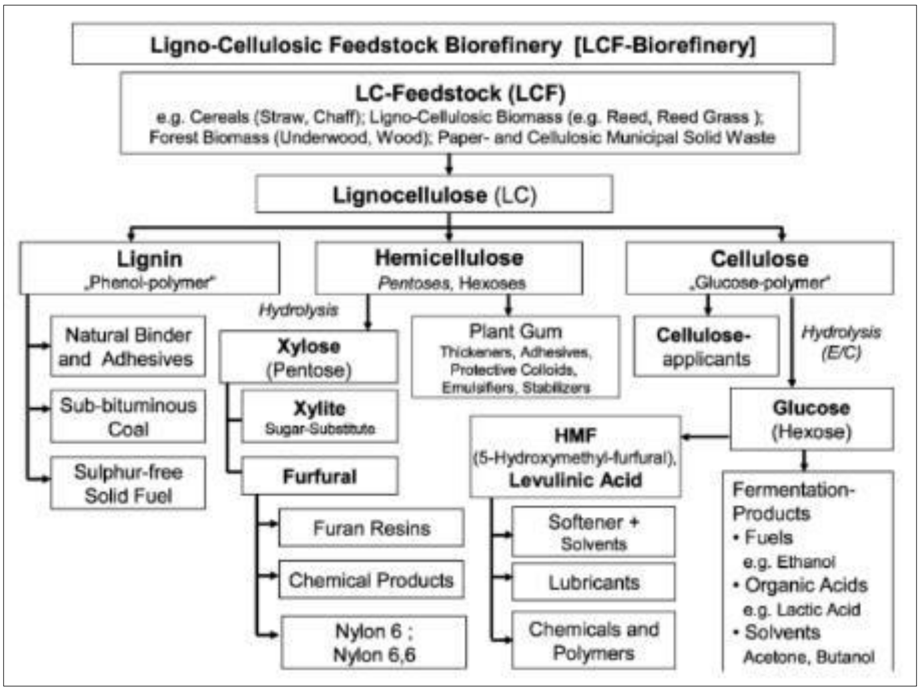


Figure 10 Valorisation Lignocellulose Biomass [24]

4.2. Baglog Processing Opportunities

Baglog is a growing medium for mushrooms; once the mushrooms are harvested, the baglog is discarded. The contaminated baglog and aged baglog are the sources of the in question baglog trash. Baglog waste is helpful for boosting soil fertility since it has been broken down by fungi during development and contains nutrients including P 0.7%, K 0.02%, total N 0.6%, and C-organic 49.00% [25].

One of the pretreatment techniques used in the widespread development of lignocellulose degradation is fungus cultivation. To investigate the incidence of degradation caused by fungal mycelium penetrating during growth (to increase pore size) and by upsetting the functional interaction between polysaccharides, cellulose, and lignin, for instance, *Volvavierra volvacea* are cultivated in lignocellulosic biomass. These an edible fungus generate lignocellulolytic enzymes, which break down lignocellulosic cell walls. Since these edible fungi (*Agaricus bisporus*, *Pleurotus ostreatus*/oyster mushrooms, and Lentinula edodes) are metabolically active, they are known to be efficient in breaking down lignin and cellulose into simple sugars and other micro-molecules that the fungi can use as food or carbon sources [26].

According to the explanation above, lignocellulosic biomass can either be utilized as a growing medium or substrate for the growth of edible fungus, or it can be processed with the culture of edible fungi. Mmanywa and Mshandete (2017) cit [26] reported that Methane production from treating palm oil waste with Coprinus cinereus was higher than that from leaving it untreated, resulting in 0.43–0.49 m3 CH4/kg VS as opposed to 0.33–0.34 m3 CH4/kg VS. According to recent research, growing fungus can lower the content of lignin by 2.67%, hemicellulose by 6.33%, and cellulose by 6.55%. By altering the lignocellulosic structure of the biomass, this method facilitates the easy degradation of organic matter into value-added products like methane and biogas by the already-existing consortia of microbes [26]. Furthermore, lignin concentration is significantly reduced in baglog waste due to lignocellulose degradation, which is dependent on the fungus's length of cultivation [27].

5. Conclusion

An organization called LMS cultivates oyster mushrooms in Padang City's Limau Manis urban village. In three months, LMS can create 40 tons of baglog, or the same amount as one oyster mushroom farm. By using baglog, LMS has processed it to create compost, an organic fertilizer. However, industrial processing to create several goods in a single processing step known as valorization is another innovation that may be done to further boost product value added. Because lignocellulose waste can be used to create a variety of derivative goods, such as biofuels, bioethanol, biochemicals, and more, it is a major concern today.

Compliance with ethical standards

Disclosure of conflict of interest

Author declares no conflict of interest.

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