PROFITABILITY OF CHIPPED ALDER AS SUBSTRATE FOR SHIITAKE PRODUCTION

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ABSTRACT

Substrate mixture having the greatest amount (63%) of chipped Alder (*Alnus japonica*) with mesh sieve size between #8 (2.38 mm) and #6 (3.33 mm) combined with small amount (21%) of commercial sawdust having mainly mesh sieve size ≤1.41 mm, produced shiitake fruiting bags with the shortest incubation period of 50.8 days, and highest biological efficiency of about 50%. The same mixture had the highest additional benefits (PhP8,452.50 per 300 fruiting bags) and return above variable cost (16.57). This trend is followed by mixing equal part of chipped alder and sawdust.

Conversely, the use of commercial sawdust alone resulted in the longest incubation period as well as lowest yield of 137 g and biological efficiency of 31.12% ; consequently having the lowest additional benefits and return on variable cost of PhP2,577 per 300 fruiting bags and 10.74, respectively.

The technology of utilizing chipped pruned twigs of alder as substrate for producing shiitake as a high valued crop would add to promoting alder as a well-adopted multi-purpose tree species in the highlands to address climate change and promote resource-based mushroom industry.

Keywords: Shiitake, alder, wood chip particle size, growing bags, biological efficiency, profitability

INTRODUCTION

Shiitake (*Lentinula edodes*) ranks second to button mushroom (*Agaricus spp.*) in total world production and is also one of the nutriceuticals being promoted (Chang and Miles, 2004). With the rising incidence of virus diseases such as the popular pandemic AIDS and Ebola, people are in search for nutriceutical products with immuno-restoring properties. Thus, this research concerns producing nutriceutical organic products like shiitake, which have been reported to have nutriceutical properties (Chang and Miles, 2004; Ooi, 2000).

Sawdust from lumber yards is commonly used as substrate for shiitake production. However, the availability of sawdust cannot be guaranteed considering preference on use of steel over wood by house builders nowadays.

There is a need to find alternative substrate sources for shiitake production from among locally available broad-leaf trees such as alder (*Alnus spp.*). While alder is one of those being used for shiitake log production (Przybylowics and Donoghue. 1990), it has not been earlier explored for use in shredded or chipped form so as to utilize smaller branches or twigs.

The process of utilizing wood chips would motivate farmers to plant trees will not only as a measure to address climate change and other positive effects of reforestation including carbon sequestration, water conservation, prevention of soil erosion, as windbreaks, wood source and nitrogen source from its foliage compost. Promotion of its use as substrate for shiitake production especially as wood chips would revolutionize shiitake production in the country as source of livelihood and income.Wood chip particle size influences shiitake yield. The particle size from 0.85 to 1.7 mm produces the highest yield as compared to other sizes outside of this size but not significantly different from particle size between 2.8 to 4 mm. The more water gain during soaking for smaller particle sizes less than 0.85 mm had contributed to low yield (Royse and Sanchez-Vasquez, 2001). Earlier, Ogha (1990) as cited by Royse and Sanchez-Vasquez (2001) demonstrated that vegetative growth rate of shiitake mycelium decreased as particle size decreased and attributed that oxygen depletion was the reason for such reduced mycelia growth.

Donoghue and Dennison (1995, 1996) as cited by Royse and Sanchez-Vasquez (2001) also showed that oxygen and carbon dioxide levels in the airspace above incubating substrate were correlated with subsequent mushroom yield; concluding then that small air space found in small particle size less than 0.85 mm may slow gas exchange from deep within the interior synthetic log would have chip size towards the surface of the log. In cases when sawdust or wood chips may not necessarily be of particle size desired for mycelia growth of shiitake, understanding the combination of sizes that may attain optimal yield would greatly help the shiitake production industry.

It must be noted that locally-fabricated wood chippers do not necessarily produce uniform wood chip size; but rather of sizes usually greater than 1 mm. Thus, a compromise on wood chip sizes between available sawdust and those to be chipped for substrate mixture that would impact high yield would be worth looking at.

OBJECTIVES

The study was conducted to determine the appropriate ratio of *Alnus* wood chips with commercial sawdust as main substrate for the production of shiitake and compare costs and returns among the treatments.

MATERIALS AND METHODS

Shredded *Alnus* and sawdust as the main substrates were sieved separately using mesh sieves of various apertures including mesh sieves #8 (2.38 mm), #6 (3.33 mm) and #14 and were then mixed with the other components following four substrate combinations as treatments; viz.

T_0 - Sawdust + Rice bran + Lime (84:15:1)

T_1 - Sawdust + shredded *Alnus* branch + Rice bran + Lime (63:21:15:1)

T_2 - Sawdust + shredded *Alnus* branch + Rice bran + Lime (42:42:15:1)

T_3 - Sawdust + shredded *Alnus* branch + Rice bran + Lime (21:63:15:1)

The substrate mixtures were packed into polypropylene bags, each bag containing 1,100 g fresh weight (440 g dry weight) of the mixture. The substrates were sterilized at 20 PSI for three hr, cooled overnight and inoculated with shiitake spawn.

Each treatment was replicated five times with 10 bags per replicate and arranged following the CRD inside the incubation room and in the fruiting house. The number of pricked polypropylene bags as due by the sharp shredded *Alnus* were counted. Also noted were the incubation period of the inoculated bags, yield and percent biological efficiency, taken by dividing weight of fresh mushroom yield with the corresponding substrate dry weight matter content X 100% (Royse, 1985).The costs of producing the bags including those of the sawdust, shredded *Alnus*, lime, rice bran, polypropylene bags, polypipe rings and plugs were determined as bases in computing the returns on cash expense, returns above variable cost of and additional benefits in adopting the treatments as technologies.

RESULTS AND DISCUSSION

Main substrate particle size

Majority (65%) of the chipped *Alnus* used had particle size from 3 to 4 mm while 62% of commercial sawdust, which was used in the check treatment, had less than 1 mm particle size (Table 1). With the combination, T_1 had 71% sawdust of particle sizes 1-2 mm and 17% chipped *Alnus* with an average of 65% particle size at <3-4 mm. T_2 had mainly 31% sawdust of 1-2 mm particle size and 34% chipped *Alnus* of 3-4 mm particle sizes. T_3 mainly contained 50% chipped *Alnus* of 3-4 mm particles size and 16% sawdust of 1-2 mm particle size; with 65% at 3-4 mm.

Table 1. Percentage distribution of particle sizes of sawdust and chipped alnus.

TREAT-MENT	Commercial Sawdust			Chipped Alnus			AVE. PARTICLE SIZE
	% IN RATIO	%@<1 mm	%@1-2 mm	% IN RATIO	%@3-4mm	%@≥4 mm	
T_0	84	62	22	-	-	-	62%@ <1 mm
T_1	63	16	71	21	17	4	65% @ <3-4 mm
T_2	42	11	31	42	34	8	30-40% @3-4 mm
T_3	21	5	16	63	50	13	65% @ 3-4 mm

Pricking incidence of polypropylene bag

The treatment (T_3) having the greatest (63%) chipped Alnus combined with 21% sawdust had the highest (17%) incidence of bag pricking followed by T_2 and the control. No pricking occurred in the treatment (T_1) having the least (21%) chipped Alnus combined with 63% sawdust (Table 2). The wood chips have sharp edges that cause pricking when pressed onto the bag, which under manual packing system may result in higher incidence of contamination if not sealed with tape.

Incubation period of the inoculated bags

The treatment (T_3) having the greatest (63%) chipped Alnus combined with 21% sawdust had the shortest incubation period while that with sawdust alone had the longest incubation period (Table 2). This is expected as air space is greater with greater mesh size giving way for mycelia to colonize earlier than when the substrates are so compact as noted in the control treatment with sawdust alone. Donoghue and Dennison (1995, 1996) as cited by Royse and Sanchez-Vasquez (2001) indicated that small air space found in small particle size (less than 0.85 mm) slows down gas exchange within the interior synthetic log causing colonization of the substrate by the mycelia.

Yield and biological efficiency

The highest yield was obtained in the treatment (T3) having substrates with the greatest (63%) chipped Alnus, that mainly contained 65% chipped Alnus of 3 - 4 mm particles sizes, and 16% sawdust of 1 - 2 mm particle size but not significantly different from the other treatments containing chipped *Alnus* of lower amount (Table 2; Figures 1 - 3). Substrates having down to 50% chipped Alnus had significantly higher yield to the control treatment.

Table 2. Bag pricking incidence, incubation period, yield and biological efficiency of the substrate mixture

TREAT-MENT		PERCENTAGE BAG PRICKING	INCUBATION PERIOD (Days)	YIELD (G)	BIOLOGICAL EFFICIENCY (%)
T0 $_0$	Sawdust with 62%@ <1 mm	3.00	71.62^{d}	136.96^{b}	31.12
T1 $_1$	65% @ <3-4 mm	0.00	58.20^{c}	171.78^{ab}	39.04
T2 $_2$	30-40% @3-4 mm	10.00	52.36^{b}	200.76^{a}	45.63
T3 $_3$	65% @ 3-4 mm	16.67	50.82^{a}	219.50^{a}	49.89
Probability		<0.01 **		0.024*	

Means with the same letter within a column are not significantly different by DMRT (P<0.05)

** - Highly significant * - Significant

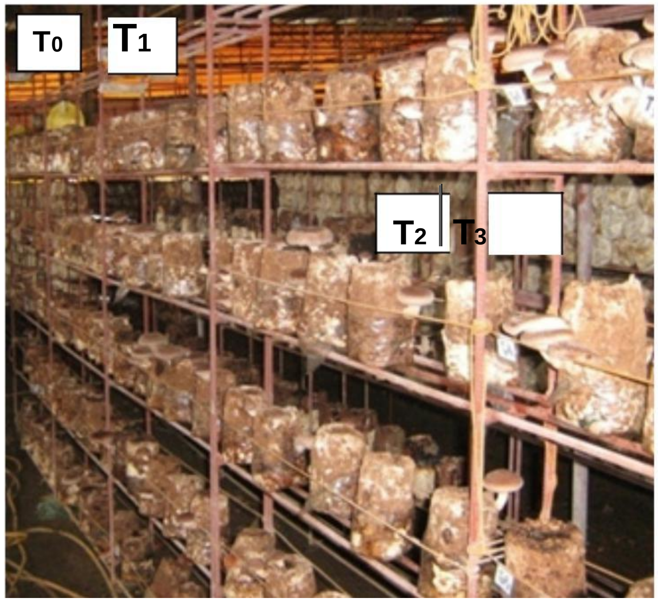

Figure 1. The treatments (T_0 to T_3) were arranged from left to right and their replications (R_1 to R_5) from top to bottom onto the fruiting racks.

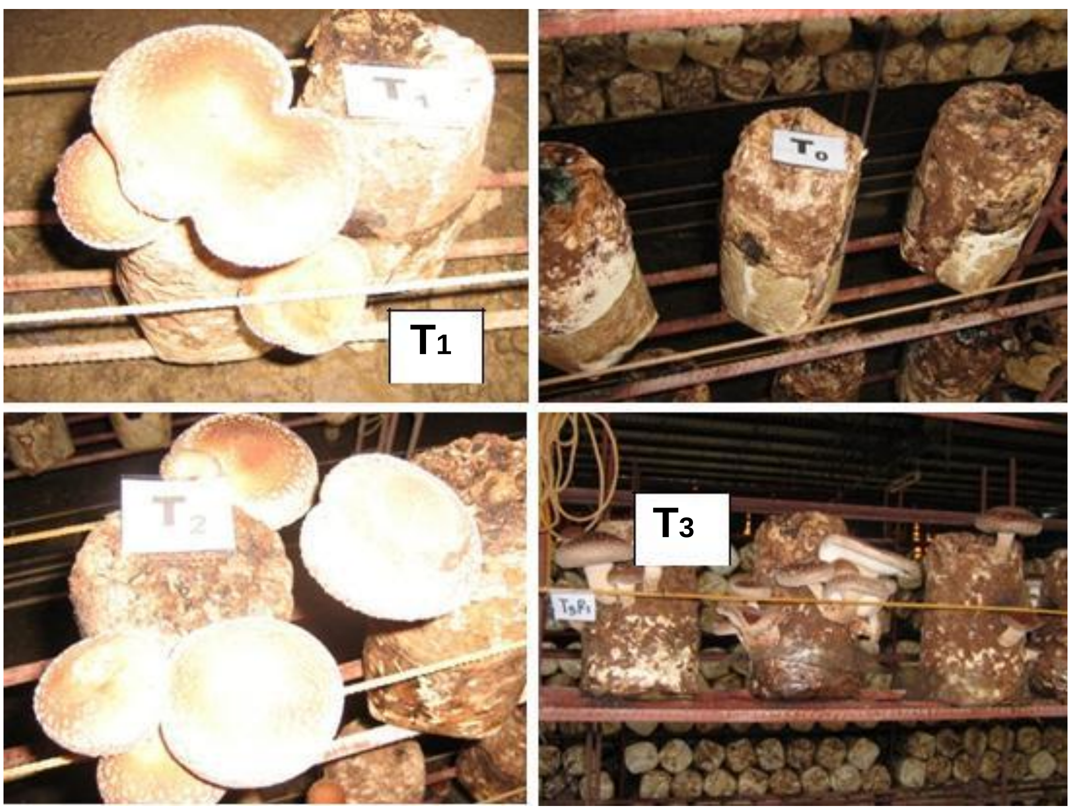

Figure 2. The compactness of the substrates without chipped *Alnus* (T_0) resulted in lower yield compared to the other treatments with chipped Alnus (T_1, T_2 and T_3).

Figure 3. Yield on fruiting bags having chipped *Alnus* increasing from 21 parts, 42 and further to 63 parts indicate potential of adding such chips into the substrate for organic production of shiitake

It follows that the biological efficiency is highest (49.88%) in the treatment combining 65% chipped Alnus of 3 - 4 mm particle size and 16% sawdust of 1 - 2 mm particle size; turning about half of the main substrate weight into mushroom.

Gas exchange within the substrate which is likely greater in T_3 than the rest of the treatments would have attributed such yield differences. Donoghue and Dennison (1995, 1996) as cited by Royse and Sanchez-Vasquez (2001) noted that small air space due by small particle size (less than 0.85 mm) lessens gas exchange within the interior synthetic log resulting in low yield.

Royse and Sanchez-Vasquez (2001) reported that particle size from 0.85 to 1.7 mm produced the highest shiitake yield as compared to smaller size.

Given sawdust as locally available but with mesh size mostly less than 1 mm and chipped *Alnus* that can be chipped but mostly at 4 mm size, the search for the best ratio between small and large particle sizes is paramount.

Economic analyses of the treatments

Difference in yield among the treatments versus control. The highest difference in yield among the substrate mixtures relative to the control treatment was obtained in the treatment having the greatest chipped *Alnus* and lowest with those given just a quarter volume of wood chips (Table 3). Such trend follows the value of difference as highest with fruiting bags having the highest wood chips added to the mixture and lowest when just a quarter of wood chips was added.

At the current price of PhP250 per kilo of fresh produce, the difference in price is highest (PhP20.60) likewise to the fruiting bags with the greatest chipped *Alnus* added.

So, with 5,000 fruiting bags as normally taken cared for by one mushroom grower in one production cycle, a net return advantage of PhP103, 000 can be generated when compared to using sawdust alone as main substrate.

Returns on cash expense. The highest returns on cash expense of PhP28.30 per bag was obtained in the treatment having the greatest alnus wood chips and lowest with those without chipped *Alnus* (Table 4). The difference in expenses is attributed by the cost of the sawdust or chipped *Alnus*; wood chip being more expensive by PhP35 per sack than sawdust.

Additional benefits in adopting technologies. Relative to the use of sawdust alone, fresh produce) was highest (PhP8,452.50) in the treatment having the greatest *Alnus* wood chips while lowest with the least chipped *Alnus* (Table 5). Likewise, the highest return on variable cost was obtained in the treatment having the greatest chipped *Alnus*. Said returns were attributed mainly by higher yield. The additional cost from the chipped *Alnus* (Table 6) was neutralized by the higher value of produce.

Table 3. Differences in yield and corresponding values of the substrate mixtures relative to the control treatment

TREATMENT	YIELD (g)	WEIGHT (g) DIFFERENCE WITH T_0	VALUE (PhP) OF DIFFERENCE @P250/KG
T_0	136.96	-	-
T_1	171.78	34.82	8.70
T_2	200.76	63.80	15.95
T_3	219.50	82.54	20.60

Table 4. Returns on cash expense and returns above variable cost of the treatments

TREATMENT	GROSS YIELD VALUE (PhP)*	EXPENSES (PhP)	ROCE (PhP)
T_0	34.25	25.65	8.60
T_1	43.00	26.00	17.00
T_2	50.25	26.35	23.90
T_3	55.00	26.70	28.30

* - @ PhP 250/kg

Table 5. Additional benefits (PhP/300 fruiting bags) in adopting technologies

EXPLANATION	T_0	T_1	T_2	T_3	EFFECT IN INCOME		
					T_1	T_2	T_3
Sales	10,272.00	12,883.50	15,060	16,462.50			
Cost of Production	7,695.00	7,800.00	7,905	8,010.00			
Additional Benefits in adopting Technology	2,577.00	5,083.50	7,155	8,452.50	2,506.50	4,578.00	5,875.50
RAVC	10.74	14.52	16.26	16.57			

Table 6. Fixed and variable costs of the sawdust and chipped Alnus in the treatments

TREAT-MENT	FIXED COST OF SAWDUST (PhP)	VARIABLE COST FROM SAWDUST AND WOOD CHIPS (PhP)	TOTAL (PhP)
T_0	60	180	240
T_1	60	270	350
2_2	60	380	440
T_3	60	450	510

CONCLUSIONS AND RECOMMENDATIONS

Combining a greater portion (65%) of chipped *Alnus* having 3-4 mm particle size with small amount (21%) of sawdust mainly <1 mm particle size for use in shiitake production can result in high yield, biological efficiency, additional benefits and return on variable cost and is, therefore, highly recommended.

Care must be observed, however, during packing of the substrate to avoid pricking of the bags, thereby avoiding contamination.

Given local availability of *Alnus* as source of chipped wood to be combined with locally available sawdust as main substrate for shiitake growing on bags, it is paramount to inculcate sustainable reforestation and management with *Alnus*; consequently sustaining shiitake production using the technology.

Promotion of the technology as component in agro-forestry undertaking would necessitate involvement of stakeholders including farmers, land-owners, NGO's involved in reforestation and development as well as government agencies such as the Department of Environment and Natural Resources, Department of Agriculture and Department of Agrarian Reform towards sustaining *Alnus* as substrate source for shiitake production.

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