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TECHNICAL AND ECONOMIC ASPECTS OF PRODUCING MUSHROOMS IN THE CARIBBEAN

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ABSTRACT

The use of agricultural and/or industrial waste materials as a substrate by micro-organisms is an environmentally friendly biotechnology for sustainable development. An efficient biological agent for the reduction of lignocellulosic materials, a component of agricultural waste, is mushroom mycelium. It is well known that a number of mushroom species are edible, having high protein content with balanced amino acids and several vitamins, as well as some high-value metabolites. Mushroom production could therefore, play an important role in the Caribbean by helping to solve the problem of providing high quality protein. It can also contribute to foreign exchange savings by reducing the levels of current imports. The paper investigates the technical and economic possibility of producing tropical mushrooms, and the potential for their incorporation into the agricultural sector in the Caribbean.

INTRODUCTION

Mushrooms are the fruit bodies of edible fungi. In nature, fungi have a fundamental role in the biological equilibrium. They are responsible for the degradation and transformation of plant and animal substances and the restoration of soil fertility by returning to the soil the biodegraded organic matter. One use of fungi in agriculture is the cultivation of mushrooms as a source of food.

The popularity of mushrooms is not only due to their culinary value but also to their potential as a source of protein. The protein content is almost equal to that of milk and legumes with an excellent amino acid profile. Besides, they are high in vitamin content.

In developing countries, including those in the Caribbean, huge quantities of wastes are generated annually through agricultural, forest and food-processing industries. Conversion of these waste materials to food and useful products by fungi is an environmentally sound biotechnology.

There has been very little research conducted on tropical mushrooms. Ghana (Anon, 1992) and Zaire (Ekwangala and Comte, 1990) have explored their native species and those countries are among the leading tropical mushroom producers in the world. Although, in the Caribbean, the native species have not been explored, in Jamaica and other Caribbean

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countries species of edible mushrooms are evident in the woods and eaten by the locals. With the recent thrust of agricultural diversification in the Caribbean, developing a sustainable mushroom industry should be a feasible option.

CURRENT MUSHROOM PRODUCTION IN THE CARIBBEAN

In Jamaica, coffee waste is used to grow oyster mushrooms (Barnett, 1987). In Trinidad, button mushrooms are grown on rice straw. Dominica grows oyster mushrooms on a very small scale using bagasse. In Barbados, the mushroom industry is very much in its initial stage. There have been attempts in St Lucia to use banana waste to grow mushrooms. Cuba commercially produces oyster mushroom using dry sugarcane waste (trash).

Mushrooms can be successfully cultivated on many substrates (Oei, 1993). Wastes such as cotton stalks can be pulverised and used to grow mushrooms and the spent substrate can be utilised as animal feed (Anon., 1993). Table 1 gives information on the major agricultural wastes available in several Caribbean countries and the mushroom species suitable for growing on them. The levels of efficiency of several types of substrates are presented in Table 2. Biological efficiency is defined as the fresh mass of mushrooms divided by the dry mass of substrate (Brennman and Guttman, 1994).

Table 1 Agricultural and other wastes available in several Caribbean countries and suitable mushroom species

Agricultural waste	Countries	Suitable mushroom species to grow
Bagasse, sugar-cane leaves	Barbados, Trinidad, Cuba, Grenada Dominica, St Kitts, Jamaica, Guyana	*Pleurotus*
Cotton straw	Barbados, St Kitts	*Pleurotus, Volvariella*
Rice straw	Trinidad, Guyana	*Pleurotus, Volvariella, Agaricus*
Coffee waste	Jamaica, Dominica, Trinidad	*Pleurotus, Lentinus*
Banana tree waste	St Lucia, St Vincent, Dominica Grenada	*Pleurotus*
Bean straw	All countries	*Pleurotus*
Paper	All countries	*Pleurotus*
Cocoa shell waste	Dominica, Trinidad, Grenada	Pleurotus
Saw dust	All countries	*Pleurotus, Lentinus*
Forage grasses	All countries	*Auricularia, Pleurotus*

One advantage of growing oyster mushrooms is that they do not need a composted substrate. Another major advantage of mushroom growing is that arable land is not needed. Unused stalls, sheds, warehouses, cellars, etc. can be economically transformed into suitable growing structures without an excessive outlay of capital.

Mushrooms can be produced in elaborate structures using high levels of technologies or as small cottage industry units using simple structures. Shelves with tiers can be used to maximize the area. Some containers suitable for growing tropical mushrooms are plastic bags or trays. It is important that the temperature and high humidity inside these containers are maintained to the requirements. If the trays do not have covers, they need to be covered by black plastic.

As can be seen from Table 2, bagasse is an excellent substrate for growing oyster mushrooms. The substrate (bagasse) should be as clean as possible, soaked overnight in lime water and drained to about 70% moisture content. For commercial production, pasteurization of the bagasse in a steam room at 60 °C for 3 hours to ensure that it is free of all the contaminants is recommended. The substrate is then mixed with 5% corn meal and placed in trays or bags seeded with spawn and kept under suitable environmental conditions for mycelial growth. It should be left in total darkness for about 20 days until the white filaments (mycelia) have grown out.

Light is then introduced; diffused natural light or artificial light with the daylight spectrum is recommended. During this period fresh air is also introduced. Within 10-12 days pinheads appear. Four days later, 'fruits' can be ready for harvesting. Over a 3-week period three flushes of mushrooms can be harvested. The expected yield is about 1 kg of fresh mushrooms per kg of substrate dry matter. The environmental conditions required for optimum growth are presented in Table 3.

Table 2 Biological efficiency of substrates

Substrate	Biological efficiency (%)
Bagasse/cane trash	51
Straw	57
Grass	40
Corn leaves/banana plant waste	38
Sawdust	10
Paper	22

Table 3 Optimum conditions for production of the mushroom, *Pleurotus sajor-caju*

Stage/parameter	Spawn run	Pinhead initiation	Cropping
Duration (days)	20	8-12	30
Temperature (°C)	25-28	25	25
Light	Nil	diffused	diffused
RH (%)	90-95	95	90-95
Number of air exchanges/hour	0	4	4
Carbon dioxide (%)	20	0.6	0.6

EXPERIENCE WITH MUSHROOM PRODUCTION IN BARBADOS

In keeping with the recent thrust of agricultural diversification in the Caribbean, a pilot project on mushroom production was executed by the Barbados Agricultural Society, funded by the Canada Fund of the Canadian High Commission in Barbados. The effects of the various environmental conditions on production are briefly discussed below.

Inadequate lighting can result in a limited number of pinheads, abnormal fruiting bodies and long stems with underdeveloped fruit bodies, resulting in an overall low yield. When florescent light was used during fruiting, the mushroom selected (*Pleurotus sajor-caju*) developed pinheads with long stems that failed to develop as full fruit bodies. However, when Gro-lux light or diffused natural light was used, fruiting was normal (Table 4).

Table 4 Effect of the lighting system on the production of the mushroom, *Pleurotus sajor-caju*

Type of light	Total mass (g)	Ratio of cap mass to stalk mass
Warm fluorescent	500	150:350
Gro-lux	500	350:150
Diffused sunlight*	500	350:150

* Produced short thick stem

P. sajor-caju can withstand temperatures up to 30 °C. However when non-composted, sanitized substrate was used in plastic bags, during the spawn run the temperature inside the bags tended to rise due to bacterial action. Regular monitoring of the temperature inside the bags as well as outside was required to ensure that the temperature was maintained within the optimum range.

For the trials at the Barbados Agricultural Society, two different growing room structures were used. The first type was a room with insulated walls. The second type was a low-cost hut made out of 3.75 cm thick foam and lined with crocus bags. Under the local environmental conditions, due to excessive dryness, frequent misting was needed to maintain the correct humidity in the huts. Misting twice a day, morning and afternoon, with a fine mister was enough to maintain the required humidity in the room with insulated walls.

Adequate air exchange is necessary to prevent build-up of high levels of carbon dioxide. The maximum amount of carbon dioxide should be 1,500 ppm. At the same time, the correct oxygen balance must be maintained. In general, the air exchange required is 25 m3/h per m^2 (Stamets and Chilton, 1983). This parameter was adequately met using a simple fan system with a filter.

Flies were the main pest problem. The room used was not fly-screened. During the spawn run the fruit flies laid their eggs and the larvae fed on the mycelium. This was a major problem encountered using unpasteurized substrates, due to the fruity smell of the wet bagasse. On pasteurized bagasse, this problem was not encountered. Other problems were cockroaches, mice and rats. They all made holes in the bags and fed on the mycelium and the spawn grain.

During the fruiting cycle, mushroom flies (sciarid fly) appeared in the huts. The flies fed on the pinheads and mushrooms and left holes on the mushroom and affected the appearance. Also damaged pinheads were deformed when matured. These flies were controlled by smoking the huts twice a day.

Other contaminating fungi were not much of a problem if the bagasse was fresh. On occasions when old bagasse (bagasse that was left outside the factories for long time) was used without pasteurization, the contaminants outgrew the mushroom mycelium and reduced the yield to nothing. This suggests that if old bagasse is used pasteurization is essential.

Other problems encountered were: controlling the optimum moisture contents of the substrate; determining the correct inoculum level; over-compaction of the substrate. These problems can be overcome by proper staff training.

SOME ECONOMIC ASPECTS OF MUSHROOM PRODUCTION

Except for Barbados, the trade classification does not allow data on import of fresh and processed mushrooms in the eastern Caribbean countries to be singled out. For the other countries only mushrooms preserved in brine solution can be identified. Information on imports is presented in Table 5.

The largest importer of mushrooms among East Caribbean countries has been Barbados followed by St Lucia and Antigua (Table 5). During the period 1988 to 1994, the per kilogram c.i.f. cost of processed mushrooms ranged from a low of US$1.90 to US$4.80.

During that period also, the c.i.f. cost of fresh mushrooms imported into Barbados ranged between US$4.50 and US$10.50/kg.

Table 6 gives a crude indication of 'per-day' mushroom import equivalent into eastern Caribbean countries for the period 1988 to 1994. The per-day import is computed by dividing the annual import by 365, and gives an indication of daily production levels which will be required to meet the imported demand. By far, Barbados registered the largest per-day import equivalent. Processed mushrooms ranged from between 10 kg in 1991 and 31 kg in 1994. For Dominica, the data show a decreasing trend of processed mushroom import volume. In 1991 for example, approximately 6 kg/day equivalent were imported. By 1991, the volume dropped to 1 kg. A possible explanation for the decreased import is the local production of P. sajor-caju which began and substituted for imported processed mushrooms.

Mushrooms can be produced commercially using high level technology or small cottage industry operations. Resource requirements and estimated costs of production for each are presented in Tables 7 and 8. Under a high technology scenario, a unit for producing approximately 45 kg/day will require an investment estimated at US$83,375 for buildings and about US$98,325 for equipment. Annual operating costs are estimated at US$102,630. The individual item costs are shown in Table 7.

Fresh mushrooms presently retail for approximately US$18/kg. With a farm-gate price of US$13/kg, investment into a 45 kg/day unit could potentially yield a rate of return of around 30%.

The costs associated with a cottage industry type operation for producing around 2 kg/day are shown in Table 8. Due to the relatively low level of investment required, such an operation could potentially yield an extremely high rate of return of around 235%.

Table 5 Import volume (kg) and c.i.f. cost (US$/kg) of mushroom for eastern Caribbean countries, 1988–1994

	1988		1989		1990		1991		1992		1993		1994	
Country	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost
Antigua	8,002	2.96	5,336	2.60										
Barbados														
Fresh							7,487	10.50	7,524	6.50	7,748	5.00	1,141	4.50
Processed									2,484	3.00	2,302	2.00	4,569	2.50
Dominica	2,191	2.60	1,545	2.20	947	3.30	364	5.20						
Grenada	3,158	3.70	1,582	4.80	4,056	3.30	2,415	2.60	4,602	3.30				
St Kitts	3,558	1.85	1,983	4.07	2,931	2.96			1,705	3.30				
St Lucia	1,227	3.30	5,622	4.80	8,318	2.60								
St Vincent							4,061	2.96	1,509	4.45				

Table 6 'Per-day' mushroom import equivalent into selected eastern Caribbean countries, 1988–94

Country	1988	1989	1990	1991	1992	1993	1994
Antigua	22	16					
Barbados: Fresh				10	20	21	31
Processed					68	63	125
Dominica	6	4	3	1			
Grenada	9	4	11	7	13		
St. Kitts	10	5	8		5		
St. Lucia	3	15	23				

Both capital and operating costs are involved in the production of mushrooms. To determine the production cost per unit, the capital costs must be expressed on an annual basis. For capital items, the annual cost is not simply the total cost divided by the total life. The declining future value of an investment must be accounted for based on its marginal productivity.

For the 45 kg/day mushroom production unit, the annualized capital cost is US$32,158 (See Appendix). Cost per year is estimated as the sum of the annualized capital cost and the operating cost for the year (US$32,158 + US$102,630) = US$134,788, with a production cost of US$8.47/kg.

For the cottage industry type production unit, the annualized capital cost is US$925. The total annual cost of producing mushrooms under this scenario is US$(925+5929) = US$6854. The cost will therefore be around US$9.42/kg.

CONCLUSIONS

Tropical mushroom production in the eastern Caribbean can be technically and economically feasible. However, the major constraint to the development of a viable industry is that there is insufficient know-how among local personnel on various aspects of mushroom production. A 'learning by doing' training approach should be adopted to overcome this constraint.

While imports into most Caribbean countries seem relatively small, a promotional programme could develop awareness among consumers as to the nutritive value of mushrooms. This could result in an increased local consumption and demand. Furthermore, a niche export market for 'Caribbean Mushroom' can be developed. A sustainable mushroom industry could therefore contribute to the ongoing agricultural diversification process in the Caribbean.

Table 7 Estimated project costs and returns for the production of *Pleutotus sajor-caju* in mushroom Barbados.(commercial enterprise)

Cost category	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Total building & equipt.costs*	181700									
Laboratory techn.	3750	3750	3750	3750	3750	3750	3750	3750	3750	3750
Wheat grain	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Cooking gas	50	50	50	50	50	50	50	50	50	50
Inoculation supp.	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Chemicals & supp..	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Total spawn production cost	18800	18800	18800	18800	18800	18800	18800	18800	18800	18800
Field techns (3)	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Project manager	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Driver/mechanic	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
Bagasse (30 tons)	500	500	500	500	500	500	500	500	500	500
Electricity	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Water	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Repairs and maintenance	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Chemicals	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Insurance	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
Marketing	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Packaging	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Contingencies	9330	9330	9330	9330	9330	9330	9330	9330	9330	9330
Operating cost subtotal	102,630	102,630	102,630	102,630	102,630	102,630	102,630	102,630	102,630	102,630
Total costs	**284,330**	**102,630**	**102,630**	**102,630**	**102,630**	**102,630**	**102,630**	**102,630**	**102,630**	**102,630**
Income										
Oyster mushroom										
Production (kg)	909	11364	15909	15909	15909	15909	15909	15909	15909	15909
Production (US$)	12000	150000	210000	210000	210000	210000	210000	210000	210000	210000
Net benefits	-272330	47370	107370	107370	107370	107370	107370	107370	107370	107370
Net present value	246193									
Internal rate of return	31%									

***Equipment costs – Year 1 only**

Storage sheds (300 sq. ft)	3000
Preparation sheds	1500
Growing rooms	35000
Packing, storing, etc. (300 sq.ft.)	3000
Cold room (200 sq. ft)	30000
Contingencies (15%)	10875
Total building costs	**83375**

Bobcat	25500
Pickup	17500
Steam generator and tank	10000
Humidifying system	2500
Air circulating system	10000
Conveyor	3500
Monitoring equipment	2500
Shelving trays	3500
Tools	2500
Miscellaneous	8000
Contingencies	12825
Total equipment costs	**98325**

Table 8 Estimated costs and returns for the production of *Pleutotus sajor-caju* in Barbados (cottage industry)

Cost category	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Growing rooms etc.	3000									
45-gallon drum	50									
Humidifying system	150									
Air circulating system	150									
Shelving trays	1200									
Tools	100									
Miscellaneous	100									
Contingencies	475									
Total equipment costs	5225									
Spawn	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Labour	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Bagasse (1.2 tons)	40	40	40	40	40	40	40	40	40	40
Electricity	200	200	200	200	200	200	200	200	200	200
Water	100	100	100	100	100	100	100	100	100	100
Repairs and maintenance	200	200	200	200	200	200	200	200	200	200
Chemicals	50	50	50	50	50	50	50	50	50	50
Marketing	200	200	200	200	200	200	200	200	200	200
Packaging	100	100	100	100	100	100	100	100	100	100
Contingencies	539	539	539	539	539	539	539	539	539	539
Operating cost subtotal	5929	5929	5929	5929	5929	5929	5929	5929	5929	5929
Total costs	11154	5929	5929	5929	5929	5929	5929	5929	5929	5929
Income										
Production volume	727	727	727	727	727	727	727	727	727	727
Production value	9596	9596	9596	9596	9596	9596	9596	9596	9596	9596
Net benefits	-1558	3667	3667	3667	3667	3667	3667	3667	3667	3667
Net present value	$17,983									
IRR	235%									

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Appendix

The annual equivalent of an investment (capital cost) can be expressed as :

$$Acap = PV \times \frac{q}{1-(1+q)^{-n}}$$

where: Acap is the annualized capital cost
PV is the present value of the investment cost
q is the discount rate
n is the useful life of the equipment.

In the present case, taking the useful life of the capital investment as 10 years and the discount rate as 12% the annualized cost of capital expenditure used for setting up a mushroom production unit for producing 45kg/day is:

$$181,700 \times \frac{0.12}{1-(1.12)-10} = 32,158$$

Cost per year is estimated as the sum of the annualized capital cost and the operating cost for the year (US$32,158 + US$102,630) = US$134,788, with a production cost of US$8.47kg.

For the cottage type industry operation, the annualized cost is:

$$5225 \quad \times \frac{0.12}{1-(1.12)-10} = 925$$

The total cost is then (US$925 + US$5,929) = US$6,854, with a production cost of US$9.42/kg.