

## Mushroom Cultivation on Hardwood Logs

Shiitake (*Lentinula edodes*) and Oyster mushroom (*Pleurotus ostreatus*)

### *Foreword*

Through a program called “Improvement and Development of Sugarbush Resources”, professional foresters and researchers of the Faculty of forestry of the *Université de Moncton, Campus d’Edmundston* have tested different cultivation methods of mushrooms on hardwood logs in order to compare productivity of different edible species of mushrooms on different hardwood log species. This technical guide uses these results to help explain the best methods for mushroom cultivation on hardwood logs.

### ***Why cultivate mushrooms?***

Mushroom cultivation enables a woodlot owner to :

- cultivate edible and medicinal mushrooms in the forest understory;
- **diversify forest products;**
- **diversify** revenue streams;
- **value non desirable but available wood species;**
- **extend the work period** for maple producers or woodlot workforce;
- diversify employment;
- **train** a highly specialized workforce in Non Timber Forest Products;
- develop **potential markets** for specific local forest products.



#### **Did you know?**

Mushroom cultivation on logs started 2000 years ago in Asia, but has only recently gained interest among eastern Canadians.

## ***How do I cultivate mushrooms on hardwood logs?***

### ***Which tree species should I inoculate?***

Hardwood species in general are good for Shiitake and Oyster mushrooms.

**\*\* Choose your logs on the basis of the availability of hardwood species on your land.\*\***

### **Production variability based on tree species**

Generally, mushrooms inoculated on hardwood logs will take approximately 2 years before producing the first harvest. There should be an annual harvest for 6 to 7 years after that. However, if you inoculate trembling aspen your first harvest will be much sooner (1 year or less), but the years of production will be shorter (3 to 4 years).

#### **Recommended species for the cultivation of shiitake:**

- |                       |                           |
|-----------------------|---------------------------|
| ○ Alder sp.           | ○ <b>American beech*</b>  |
| ○ White birch*        | ○ Balsam poplar           |
| ○ Oak sp.             | ○ <b>Trembling aspen*</b> |
| ○ <b>Sugar maple*</b> | ○ Willow <i>sp.</i>       |
| ○ <b>Red maple*</b>   |                           |

\* Species utilized during testing

**Bold:** Inoculated species that showed good results to date with the shiitake.

#### **Recommended species for the cultivation of oyster mushrooms:**

- |                       |                     |
|-----------------------|---------------------|
| ○ <b>White birch*</b> | ○ American beech*   |
| ○ Oak sp.             | ○ Elm sp.           |
| ○ Sugar maple*        | ○ Balsam poplar     |
| ○ Red maple *         | ○ Trembling aspen*  |
| ○ Ash sp.             | ○ Willow <i>sp.</i> |

\* Species used during testing

**Bold:** Inoculated species that showed good results to date with the oyster mushroom.

**\*\*Please note that the trials with the oyster mushroom have been much less successful to date.\*\***

### **Advisory:**

- It is important to choose healthy trees.
- **Avoid logs with presence of decayed wood.** This will increase the risk of competition from pre-established fungi and will have the effect of :
  - reducing the chances of success and decreasing productivity of the cultivation;
  - increasing the risk of mistaking the desirable mushroom (shiitake or oyster mushroom) from a non desirable or even poisonous mushroom. This situation is potentially dangerous.

## Beech bark disease

Even though some of the beech utilized in the experiment were affected with the beech bark disease, which causes a depression in the bark of the affected region and cankerous blisters of various sizes, the production of mushrooms on these individuals worked exceptionally well during the trials. This being said, it is possible that the duration of production is shorten by the disease. However, it seems to be an excellent way to value beech logs that we tend to eliminate from forest stands because of the presence of the beech bark disease. This being said, it is still recommended to try to use the less affected beech trees.



## *Felling and bucking of trees: when and how?*

It is preferable to fell trees to be inoculated during the fall and winter months (during the period of dormancy) before inoculation. The advantages are:

- bark sticks better to the tree;
- sugar concentration in the tree is higher.

### Importance of bark on the log

The bark plays two important roles: First, the bark helps to keep the humidity in the log and second it acts as a natural barrier against other mushrooms and parasites.

**Dimension of logs:** can be variable.

**\*\*The dimension of the logs is the most important factor that can limit their manipulation. Trying to move oversized logs can be difficult and cause injury to workers.\*\***

### **Suggested dimensions:**

- length: 1.25 m (4 feet)
- diameter: 10 to 25 cm (4 to 10 inches)



**General rule:** The bigger the log, the longer it will take for the mycelium to inhabit the whole log and produce harvestable mushrooms, but the log will produce for a longer period of time and vice versa.

## ***Where should the logs be placed for the cultivation of mushrooms?***

The ideal location for the cultivation of mushrooms should be **warm, humid and shaded**. It is important to have good air circulation and to be close to a water source. These elements will help the development of mushrooms. In essence, the site should be:

- in the understory of a forest stand with good crown closure to prevent direct sunlight on the logs;
- ideally close to a water source to help with watering the logs if needed;
- at the bottom of a slope or in a basin which typically have higher humidity;
- on a south facing slope in order to favour the warming of the logs.



### **Important:**

The chosen site must be accessible and relatively close. This enables easy and regular follow-ups of the production site and cuts down transportation costs, especially during the harvesting phase which must be done daily.



### **Alternative version:**

It is also possible to inoculate fresh tree stumps.

## ***Which mushrooms should I try, under which form should they be bought and where do I acquire them?***

### **Mushroom species:**

Several species of mushrooms are available for cultivation.

The trials conducted by the researchers of the Faculty of forestry focused on the following species for their availability and market potential:

- Two edible mushrooms - shiitake and oyster mushrooms
- One medicinal mushroom - yamabusitake (*Hericium erinaceum*)

***Oyster mushroom (Pleurotus ostreatus) :***

- Indigenous mushroom which simplifies cultivation in our latitudes;
- Mushroom with gills under the cap of 5 to 20 cm in diameter at maturity;
- Short incubation period which enables harvest within the fall of year of inoculation;
- Productivity is good on hardwood but especially beech;
- Produces all season long (from spring to fall);
- Worldwide markets exist;
- High nutritional (protein, amino-acids, group B vitamins) and mineral (phosphate, potassium and iron) value;
- Contains very little fat;
- Marketing of product relatively easy.



***Shiitake (Lentinus edodes) :***

- Second most cultivated mushroom in the world;
- Exotic mushroom, but some cultivars are resistant to our climate;
- Also a gilled mushroom with a cap of 5 to 25 cm in diameter at maturity;
- Incubation period of approximately 2 years;
- Produces in spring and also in fall;
- Has excellent gastronomic qualities: firmness of flesh and very tasty;



- Conserves its properties and taste when dehydrated: easy to rehydrate (20 minutes in cold water);
- Has medicinal properties such as immune system stimulant, anti-carcinogen, anti cholesterol and anti stress;

#### **Yamabusitake (*Hericium erinaceum*) :**

- Peculiar looking mushroom with white needle type, flexible organs (looks like a mane);
- Grows to 40 cm in diameter at maturity;
- Good productivity on maple, ash, beech, elm and poplar;
- 2 years minimum incubation period;
- Produces in the spring and fall;
- Edible once it is cooked - taste like lobster;
- Has medicinal properties such as tonic for nervous system, works against digestive system disorders and acts as an anti-tumour agent;
- Marketing is difficult;

- It is presently used in aids research;
- Marketing of the shiitake is relatively easy.



- Priority should be given to local market as transportation is difficult;
- Do not touch with hands as the acidity can modify the colour.

**Other mushrooms like the Reishi (*Ganoderma lucidum*) or the Jew's Ear (*Auricularia judae*) could also be cultivated.**

#### **Principal types of inoculants:**

There are two main categories of inoculants: plug spawn or bulk sawdust spawn in bags.



**Type of inoculants to favour:** plug spawn.

Plug spawn are small cylinder shaped pieces of wood pre-inoculated with a specific mycelium. They can be bought at various dealers at about 20\$ per 100 plugs (Mycoflor inc. 2007)

source : <http://ruedeslumières.mokitu.org/>



## Some suppliers of mushrooms inoculants:

### **Mycoflor Inc.**

Richard O'Breham, propriétaire

7850, chemin Stage

Stanstead (Qc) J0B 3E0

Tel: (819) 876-5972

[mycoflor@sympatico.ca](mailto:mycoflor@sympatico.ca)

<http://www.mycoflor.ca/index.html>

### **Horticlub**

2914, boulevard Curé-Labelle

Laval (Qc) H7P 5R9

Tel : 1-800-723-9071

[courrier@horticlub.com](mailto:courrier@horticlub.com)

<http://www.horticlub.com>

## ***Inoculation of the logs***

### **When?**

Ideally, the logs should be inoculated at the end of May or at the beginning of June at the latest, during the same year they were felled, in order to prevent colonization of local indigenous mushrooms that could compete with the cultivation.

### **Materials needed:**

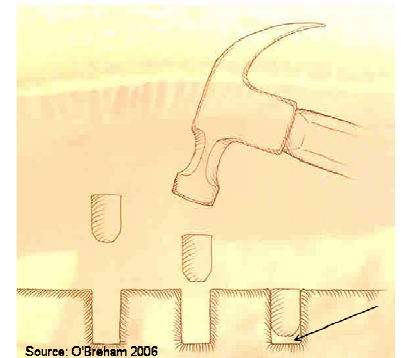
- Chain saw with proper safety equipment;
- Measuring tape;
- Work bench;
- Plug spawn;
- Battery operated drill;
- Hammer;
- Wax;
- Propane operated stove and double boiler;
- Syringe or pump;
- Aluminum tags (such as Perma Tag - available at Dendrotik) and nail to identify mushroom, inoculation date and tree species. Tags can also be created with a pop can and a permanent marker.

## How?

Once the trees have been felled, and logs cut to length, follow these instructions to inoculate your logs.

### Step 1 - Drill holes in the logs

- Depth of the holes should be approximately 3 cm in order to leave a small space underneath the plug to favour the development of the mycelium;
- Spacing of the holes should be approximately 25 cm between holes of the same row and 12.5 cm between rows;
- Note: the holes should be positioned in staggered rows;
- 4 foot logs usually require between 30 and 50 plugs;
- You can use the following formula to calculate the number of plugs needed for a specific log:
  - Number of holes =  $\frac{\text{diameter of log in cm} \times \text{length of log in cm}}{60}$



Drilling holes

### Step 2 - Insertion of Plug Spawn:

- With the plug spawn being 3/8 of an inch in diameter, you just need to insert them into the holes by gently tapping with a hammer;
- The plugs should be deeper than the surface of the bark and flush with the wood. This will enable to seal the plugged hole with wax and leave a small space underneath the plug which will encourage the process of inoculation;
- It is important to keep track of data such as mushroom type, type of wood, date of inoculation etc. This will enable you to track your success and eventually adjust to make improvements.



Insertion of plugs



### Step 3 - Seal the plugged holes (important):

- It is important to seal the holes with wax;
- The goal is to conserve humidity, eliminate chances of contamination from other poisonous mushrooms and protect the spawn from insects;
- The wax should be melted on site with the help of a propane stove and double boiler - be quick as the wax hardens rapidly;
- Retrieve and insert hot wax with a syringe;
- Apply a generous amount directly on plug until hole is completely sealed.



Sealing the holes

**Note:** Some people even recommend to seal the ends of the log to maximize humidity retention (optional).

### Time required for inoculation:

It is estimated that it takes approximately one hour for a team of 3 persons to inoculate wood with 400 plugs. It is best to work as a unit - one person drills, the next one inserts the plugs and the other one seals the holes with wax. This translates to a production of approximately 133 plugs per hour per person.

### Step 4 - Storage of the logs

There are different methods to store the logs for the incubation phase. The preferred method at the testing site was to set the inoculated logs perpendicular to 2 logs on the forest soil.

#### Advantages:

- Maintenance of humidity and good air circulation;
- Harvesting is easy by turning over the logs;
- Very little manipulation of the logs afterwards;
- Decreases the chance of contamination or premature rotting of logs since they do not touch the forest floor.



It is also possible to pile the logs in different ways for the incubation phase which should last 1 to 2 years. They should be placed in such a way that no more than one end touches the soil. For the production phase, the logs can be turned upright to help with harvesting and increase air circulation.



Possible set up for the incubation phase



Possible set up for the production phase

## Step 5 - Maintenance of the cultivation

### Irrigation

Mushrooms need humidity to grow. It might be necessary to irrigate the logs during long hot dry spells in summer time. All you need is a bucket of water. This is why it is important to store the inoculated logs near a water source.

### Water shocking your log (optional)

It is possible to induce the production of mushrooms, instead of waiting for long periods of time, by water shocking the log. You do this by leaving the log in big basin of water or a stream for 12 to 24 hours, and then you replace your log. Mushrooms should emerge in the following 24 to 48 hours. This technique, which requires much more manipulation, is not necessary but can be used to control the fructification period of the mushroom.

### Attack of the slugs

Slugs love mushrooms. This is the main reason why the harvesting needs to be done in a timely manner. There are also different ways to control the impact of slugs, such as:

- Beer bottle trap - completely burry a beer bottle upright half filled with beer so the attracted slugs drown when they fall inside;
- Scatter broken egg shells all around the production zone;



source : [www.wikipedia.ca](http://www.wikipedia.ca)

Slug

- Scatter ashes from the BBQ or from your furnace. You need a 1 cm thick layer around the production zone for it to work;
- You can also buy anti slug products.

### **Insects and other mushrooms**

Insects and other competing mushrooms can also cause severe damage to your mushroom cultivation. If signs of these organisms are present, it is preferable to remove the infected logs.

### **Weed control**

It might be necessary to control weeds twice a year (during mid-summer and fall). This step is optional but might be desired if vegetation becomes too dense or is bothersome. A certain amount of vegetation is beneficial as it contributes in keeping a high level of humidity.

### **Leaf litter control**

It is preferable to remove leaf litter that falls on the inoculated logs. The leaves can increase the risk of rot and decrease the quality of mushrooms if they come into contact with them. Leaves should be removed in springtime just before mushrooms come out.

### **Production**

A formula exists to calculate the total production of a log during its lifespan. This formula gives an approximation of the productivity, but the production depends on many variables including environmental conditions (such as temperature and humidity), initial quality of the logs, presence and control of pests, etc.

**Total production of mushrooms in weight = Dry weight of the log X Biological efficiency index (usually 30 %)**

Dry weight of the log = approximately 55% of total weight (humidity is estimated at 45%)

For example, if a log weighs 50 lbs, its dry weight would be  $50 \text{ lbs} \times 55\% = 27.5 \text{ lbs}$ . Use a unit of weight you are comfortable with.

**For this example, the quantity of mushrooms we could hope to produce from it would be:**

$$(50 \text{ lbs} \times 55\%) \times 30\% = 8.25 \text{ lbs during the lifespan of the log}$$

The length of the production phase is generally 2 to 3 years for softwood deciduous trees such as trembling aspen, and 5 to 6 years for hardwood deciduous trees such as maple or birch. It should be noted that the production phase follows the incubation phase which takes 1 to 2 years, depending on the mushroom, the log and the environmental conditions.



Production phase

### ***Harvesting***

The fruiting (production) phase usually occurs 1 to 2 years after inoculation and sometimes before or after, depending on a host of factors. The harvesting takes place during the springtime and fall, when there are large variations in temperature and more precipitation than normal which induces fruiting of the mushrooms. It is therefore necessary to visit your site regularly during the production phase and especially after rainfall to monitor production and to harvest the mushrooms. Mushrooms become inedible after 3 days to a week once they are fully developed. The longer they remain on the log, the higher the risk of attack by slugs or other insects.

### **What should the mushroom look like during harvest?**

It is recommended that the oyster mushroom be harvested before the rim is completely stretched out. The Shiitake should be harvested when the cap is still closed and the diameter is approximately 5 cm, which should occur between 2 to 7 days after the formation of the mushroom has begun.



Shiitake



Oyster mushrooms

### **Transportation of mushrooms**

To help avoid altering the mushroom, it is preferable to harvest them by cutting the very bottom of the stem. They should be placed in a container that does not inhibit air circulation. Therefore, you should use a basket, paper bag or even wax paper.

### **Preservation of mushrooms**

Fresh mushrooms can only be preserved for a short period of time; a few days to a week. Once the mushrooms have been harvested, they should be refrigerated as soon as possible at 1 to 2 degrees Celsius. It is also possible to dry the mushrooms during the same day of the harvest. Different tools and methods can be utilized such as an oven heated at 60°C or even the sun. Drying the mushrooms does not alter the Shiitake at all. Once rehydrated, they have the same texture and taste. In order to rehydrate the mushroom, all you need to do is soak it in cold water for 20 minutes.

## ***Economic potential and marketing***

Costs associated with the cultivation of mushrooms on logs are mainly attributed to the workforce and the purchase of the plug spawn. The costs and revenues detailed in the following table are for information purposes only. Salary for the employees is estimated at 25\$ per hour, which includes all expenses and travel. Generally, a small profit can only be obtained if the woodlot owner does the work himself.

### **Establishment of mushroom cultivation on logs**

Inoculation of one cord of wood (4' x 8' x 8') of Trembling aspen (adapted from O'Breham 2006)

#### **Cost of inoculation**

<b>Labour (2 people @ 25\$ per hour)<sup>1</sup></b>	40 h x 25\$/h x 2	2 000.00 \$
<b>Equipment</b>		
see liste in this document <sup>2</sup>		- \$
<b>Material and micillium</b>		
1 corde of Trembling aspen		- \$
Plug spawn		1 000.00 \$
<b>Total cost</b>		<b>3 000.00 \$</b>

#### **Annual Costs**

<b>Maintenance (1 person)</b>	16 h	400.00 \$
Irrigation		
Weed control		
Leaf litter control		
Follow-up and inspection		
<b>Harvesting</b>		
During spring and fall (1 person)	16 h	400.00 \$
<b>Total annual cost</b>		<b>800.00 \$</b>

#### **Productivity**

Potential for 590 kg of mushroom during - the lifespan of the corde (approx. 5 yrs)	118kg/year
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#### **Revenues (for 5 years)**

Sale of fresh mushrooms @ approx. 8.50\$/kg or	590kg	<b>5 015.00 \$</b>
Sale of dehydrated mushrooms @ approx. 2\$/20g (loss of 90% of mass)	59 kg	<b>5 900.00 \$</b>

#### **Annual Revenues**

Fresh	118 kg	1 003.00 \$
Dehydrated	11.8 kg	1 180.00 \$

<sup>1</sup> 25\$/hour = the average cost of a day labourer including travel and expenses

<sup>2</sup> Generally, land owner has this equipment

<sup>3</sup> Tree commonly available or use species available on your land

<sup>4</sup> Hours distributed during the whole growing season



## **Marketing**

Shiitake and oyster mushrooms are popular around the world and bringing them to market is relatively easy. However, since the market for these mushrooms in Eastern Canada is underdeveloped, efforts must be directed towards marketing. It is therefore advisable to verify market conditions before starting-up your log mushroom production. Is there a market for such mushrooms? What type of price is offered for varying products (fresh vs. dehydrated mushrooms, for example)? Many opportunities may be possible by developing relationships with local gourmet cooking restaurants or by attending the local farmers market. Networking with local businesses is always a good idea.

Furthermore, since mushrooms do not conserve well over a long period of time, you may want to research the possibility of processing the mushrooms locally, either by drying them or by processing them in some other form (oils, marinades or other products).

Where markets already exists, cultivation of mushrooms for the purpose of selling part of the production presents little risks and is relatively inexpensive in time and money. Most of the material should already be available to the landowner for the exception of the plug spawn which are a very specific product.

## ***Example of a schedule for establishing a log mushroom cultivation area on your woodlot***

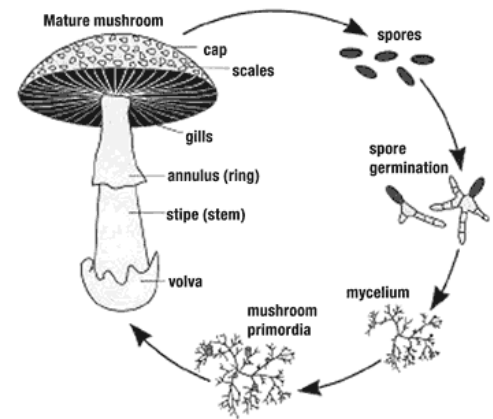
This table can be used as a reminder for the tasks to be completed at specific times of the year in order to have a successful log mushroom growing operation. It is for information purposes only. If you plan on having a mushroom growing operation for years to come it is recommended to inoculate the same amount of logs per year. By doing so, your production should be fairly constant year after year. Keep in mind that the production periods and time needed for incubation varies depending on the type of wood and mushrooms. Make sure to remove all logs that have been used up or the ones that have been infected by wild mushrooms, insects or diseases. According to some authors, if you inoculate approximately 100 logs yearly, you should have a small scale mushroom growing operation.

	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
<b>Planning</b>								
Documentation								
Market research and networking								
Gather material								
Order plug spawn								
Harvest trees and buck logs								
<b>Log mushroom operation installation</b>								
Inoculation of 100 logs per year								
<b>Maintenance</b>								
Irrigation (if needed)								
Weed control (optional)								
Leaf litter								
Inspection								
<b>Harvesting and marketing</b>								
Mushrooms harvesting								
Mushrooms processing (if needed)								
Marketing								

## *To better understand mushrooms...*

### What is a mushroom?

What we commonly call mushroom is actually only the visible part of this complex, but interesting organism. The visible part of the mushroom is called the carpophore (or sporophore) and is actually the fruiting body of the mycelium. The main role of the carpophore is to enable the reproduction of the organism.



source: [www.ont-woodlot-assoc.org](http://www.ont-woodlot-assoc.org)



Presence of mycelium at the end of this birch log indicates that the inoculation was a success.

The mycelium is composed of minuscule white filaments that can develop in various environments such as humus, wood, soil and bark among others. The mycelium is contained within the plug spawn that is inserted in the logs. After a certain period, the mycelium can be observed at the end of the logs that have been inoculated. Its presence indicates that the logs have been successfully inoculated.

When we harvest the visible part of the mushroom, the mycelium continues to inhabit its woody environment. It will produce fruit again in the future once the climatic conditions are favourable.

## ***Additional Information and Resources***

This guide is presented by the Faculty of forestry of the *Université de Moncton - Campus d'Edmundston* through a program called "Improvement and Development of Sugarbush Resources". The main objective of the program is to optimize the economic model of sugarbushes in New Brunswick by investing in development, research and technology transfer. Specifically, the program aims to meet the following objectives:

- Diversify production and find innovative new products for commercialization;
- Technology and knowledge transfer;
- Training and professionalization of the workforce.

The goal of this technical guide is to transfer knowledge acquired from recent tests conducted within the context of this program. Additional information has been added from different sources which are cited in the bibliography.

The present guide is not exhaustive but is rather a summary of information that can be used as a starting point for mushroom cultivation.

Conferences and workshops are available at the "Montagne Verte" Sugarbush. Moreover, other forestry extension materials in different aspects of the program are available for interested people. Other technical guides about the cultivation of American ginseng, wild Indian cucumber, organic fertilization in maple stands and multi-resource inventory are also available. For more information, contact Jeff Levesque or consult our web site at [www.umce.ca/foresterie/érablière](http://www.umce.ca/foresterie/érablière).

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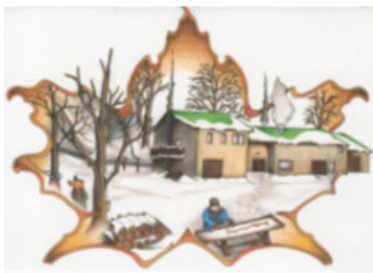
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### **CD-ROM**

- Pirot, P. 1999. Des champignons toute l'année. Éditions Génération 5. [Cd-Rom]. Adresse : paul.pirot.mycology@skynet.be

**This technical guide was created thanks to the financial contribution of the following organizations :**



## ***Recipes ...***

### **Oyster Mushrooms with Basil (4 people)\***

#### *Ingredients :*

2 cups of Oyster mushrooms  
3 tomatoes - peeled  
8 fresh basil leaves  
2 garlic cloves  
2 shallots  
olive oil  
thyme  
salt and pepper

Heat the crushed garlic in the oil until the garlic releases a pleasant smell and then add the crushed shallots, diced tomatoes, strips of the mushrooms, thyme, salt and pepper. Simmer for approximately 10 minutes. Remove from heat and let it cool down. Serve in a cup with basil leaves.

\*Adapted from "Champignons toute l'année"

### **Sautéed vegetables and Shiitake (4 people)\***

#### *Ingredients :*

1 3/4 cups of shiitake  
1/2 cup of carrots  
3 celery sticks  
1 squash  
2 ou 3 white onions  
1 garlic clove  
1/2 green pepper  
peanut oil  
salt and pepper

Peel the carrots and cut them into sticks. Peel the onions and cut them into rings. Wash the squash and cut it into sticks and remove the center. Cut the celery and the green pepper into small strips. Remove the mushroom caps. Cut the caps into fine strips. Heat the oil and put in all of the vegetables except the garlic. Cook for 3 minutes at a mid to high heat. Mix every so often. Add the garlic. Continue the cooking for another 2 minutes. Season to taste. Serve immediately with a touch of chevril.

\*Adapted from "Champignons toute l'année"

## **Enjoy!**