1. INTRODUCTION

Mushrooms, since early times, have been known as a source of human food with delicious flavor and high nutritive value. The medicinal properties of mushrooms have also been known and utilized traditionally, but still represents a relatively untapped resource for modern medicinal applications. Furthermore, the substrates used for mushroom cultivation are derived mainly from agricultural and industrial waste materials, which provide a solution to protein shortages, resource recovery and environmental management (Buswell & Chang, 1993). Due to these attributes, mushroom research and industries have been gaining more and more attention in recent years (Chang, 1993).

In general, mushrooms can be divided into four categories: (1) edible mushrooms, which are fleshy and edible, e.g. *Agaricus bisporus*; (2) medicinal mushrooms, which are considered to have medicinal properties, e.g., *Ganoderma lucidum*; (3) poisonous mushroom, which are proven or suspected to be poisonous, e.g. *Amanita phalloides* and (4) 'other mushrooms', which include a large number of mushrooms whose properties remain less defined (Chang, 1993). This form of classification is however not absolute. Many types of mushrooms can be edible and possess medicinal properties, e.g. *Lentinus edodes* (Chang, 1993).

Besides being perceived as a highly nutritious food, mushrooms have been traditionally used in China and Japan for their medicinal and tonic properties (Buswell

Today, *Ganoderma* spp. are being produced on a large scale for commercial purposes by artificial cultivation and/or submerged fermentation in over 10 countries. China is the leader in the production with an annual output of 4,300 tones. Other countries include Korea, Taiwan, Japan, USA, Malaysia, Vietnam, Indonesia and Sri Lanka. Species that are being cultivated include *G. lucidum, G. japonicum, G. applanatum, and G. tsugae* (Jong and Birmingham, 1992).

Table 1.1: Pharmaceuticals developed from mushrooms in Japan

Name	Krestin	Lentinan	Schizophyllan
Abbreviation	PSK.PSP	-	-
Date of sale	May 1977	December 1985	April 1986
Mushroom species	*Coriolus versicolor* (mycelium)	*Lentinus edodes* (fruiting body)	*Schizophyllum commune*
Polysaccharide	β-1,6 branch; β-1,3; β-1,4 main chain	β-1,6 branch; β-1,3 main chain	β-1,6 branch; β-1,3 main chain
Molecular weight	ca 100,000	ca 500,000	ca 450,000
Specific rotation	-	+ 14~22 °C (NaOH)	+18~24°C (H_2O)
Products	1g/package	1mg/vial	1g/2ml bottle
Administration	Oral	Injection	Injection
Indication	Cancer of digestive system, breast cancer, pulmonary cancer	Gastric cancer	Cervical cancer
1985 sales	US$556 million	US$85 million	US$128 million

Source: Pai et al. (1990).

Table 1.2: Pharmaceutical components of mushroom species

Pharmacodynamic	Component	Species
1. Antibacterial effect	Hirsutic acid	Many species, *Ganoderma lucidum*
2. Antibiotic	E-β-methoxyacrylate	*Oudemansiella radicata*
3. Antiviral effect	Polysaccharide, Protein	*Lentinus edodes* and *Ganoderma lucidum*
4. Cardiac tonic	Volvatoxin, Flammutoxin, Triterpenoids	*Volvariella* spp., *Ganoderma lucidum*
5. Decrease cholesterol	Eritadenine, Triterpenoids	*Collybia velutipes*, *Ganoderma lucidum*
6. Decrease blood pressure	Triterpenoids	*Ganoderma lucidum*
7. Antithrombus	5'-AMP, 5'-GMP	*Psalliota hortensis*, *Ganoderma lucidum*
8. Inhibition of PHA	r-GHP	*Psalliota hortensis*, *Lentinus edodes*
9. Antitumor	β-glucan, Cytotoxic triiterpenoids	Many species, *Hypsizygus marmoreus*, *Ganoderma tsugae*
10. Increase secretion of bile	Armillarisia A	*Armillariella tabecens*
11. Analgesic, sedative effect	Marasmic acid	*Marasmius androsaceus*

Source: Modified from Pai et al. (1990).

In contrast to the long Chinese history of cultivation of *Ganoderma* spp., the cultivation of *Ganoderma* spp. in Malaysia is a fairly new adventure. The initial cultivation was attempted by a group of farmers in 1980's during the economic

recession (Kuan, 1999). Until now, the cultivation of *Ganoderma* is still in its infancy stage. However, in a recent report, the Minister in the Prime Minister's Department has promised to help in expanding the mushroom business in Malaysia (Haniza, 1999). Together with the recent establishment of Malaysian Mushroom Research Association (MMRA), aiming to provide technical help in mushroom cultivation as well as standardization of the market price, the mushroom industry in Malaysia is definitely foreseen to boom in the next few years.

The main substrate used in cultivation of *Ganoderma* spp. is the sawdust of *Heavea brasiliensis* (pararubber tree) (Plate 1a). This easily available agroindustry residue is mixed with 6-8% rice bran and 2-5% calcium carbonate (Plate 1b) (Kuan, 1999) and packed into polyethylene bags (Plate 1c). The bags are then pasteurized by steaming for 8 hours (Plate 1d). The cooled bags are then inoculated with quality mushroom mycelium culture (the koji) (Plate 1e). They are then kept in a dark shed with average temperature of 29-32 °C for spawn running (Plate 1f, g), which takes about one month. After a month, the polyethylene bags are opened at the top to allow the fruit body to grow out (Plate 1h). It takes about another month before the *Ganoderma* can be harvested, during which the edges of basidiocarp (fruit body) turn to yellowish brown or reddish brown (Plate 1i). At this stage, the triterpene content is expected to be the highest (Chen, 1998). The basidiocarps are then sliced, air dried and sold in packets.

Plate 1 **a**: Rubber wood sawdust (substrate)
b: Mixing of sawdust with rice bran and calcium carbonate
c: Substrate is packed into plastic bags

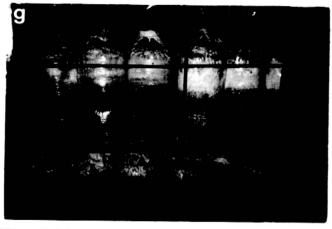

Plate 1 **g**: Spawn running (mycelium grows in solid substrate)
h: Appearance of young fruit bodies (primodia)
i: Mature fruit bodies

Currently, DXN Marketing Ltd. in Kedah, Malaysia is the major producer of *Ganoderma* fruit body and mycelium (Kuan, 1999). Other mushroom growers around Malaysia cultivate the *Ganoderma* on a smaller scale. They grow mainly the *Pleurotus sajor-caju* (grey oyster mushroom). However, due to the increasing awareness in the community of the wide-range medicinal benefits of *Ganoderma* mushrooms in treating many of the modern illness, the mushroom growers are now trying to expand the cultivation as well as the marketing of *Ganoderma* spp. In order to do so, the *Ganoderma* spp. cultivated locally have to be identified. Further, bioactive components present in the *Ganoderma* spp. need to be known and analyzed scientifically. Thus, the aims of this study are:

1. to identify the cultivated *Ganoderma* spp.
2. to extract and isolate the major compounds in the *Ganoderma* sp.
3. to characterize some of the isolated compounds and
4. to screen the isolated fractions and purified compounds for antibacterial and antifungal activities, which might be used for either nutraceutical or pharmaceutical industries

The results of this study will enable the local farmers to be informed of the active components present in the strain that they are cultivating. In addition, there is the possibility of the farmers getting a certification from the government, which will enable them to label the content of the active components. The labeling will give confidence to the consumer as well as for exportation.