EDIBLE MUSHROOMS AS FUNCTIONAL FOODS

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Mushrooms

- High in Protein (mean proportion of 33.4%)
- Low in fats (2-6% dry matter)
- Calories (20.3-74.3%)
- Relatively rich in riboflavin, niacin, ergocalciferol
- Elevated levels of phosphorus and potassium and fairly high contents of magnesium

Main Classes of Phenolic Compounds

- PHENOLIC ACIDS
- FLAVONOIDs
- ERGOTHIONEINE
  - a potential antioxidant present in most mushroom species

Antitumor, antibacterial, and antifungal properties
Anticancer Properties of Mushrooms

Clinical trials in cancer patients

**Ganoderma lucidum**
“Mushroom of Immortality”

Research in edible mushrooms is gaining popularity

Proteoglycans derived from fruiting body and mycelia of *Pleurotus ostreatus* Possess immuno-modulatory and antitumor properties

_in vitro and in vivo_ anticancer activities of _Agaricus bisporus_

Suppress aromatase activity and estrogen biosynthesis

Potential use in treatment of breast cancer

By countering the side-effects of cancer e.g. nausea, bone marrow suppression, anemia, and lowered resistance
Mushroom Samples

Pleurotus sp.

Pleurotus sajor-caju

CC 201

Pleurotus Hybrids

CC 200

Agaricus bisporus

Mushroom Unit

(Food and Agricultural Research and Extension Unit)

Harvested at optimum maturity stage

Obtained at optimum maturity stage

Methanolic extracts obtained by exhaustive extraction

Total Phenolic content

Total Flavonoid content

Total Proanthocyanidin content

HPLC Analysis

Commercially available

(S.K.C Surat and Co Ltd)
Total Phenolic content of the mushroom extracts ranged from 33.28 to 133.69 mg/g DW.

- Maximum flavonoid levels (4.63 ± 0.052 mg/g DW)
- Negligible proanthocyanidins
- Highest level of total phenolics (133.69 ± 3.204 mg/g DW)
- Negligible proanthocyanidins
## Phenolic Profile of Mushrooms

**HPLC Analysis of phenolic compounds and ergothioneine in the four mushroom extracts**

<table>
<thead>
<tr>
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**Phenolic content of mushrooms (µg/g DW)**

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**Data expressed as mean ± standard deviation (n=5); ANOVA and Fisher’s LSD Test at 5% significance level; Common superscripts between rows represent no significant difference between mushroom samples.**

**Pleurotus sajor-caju (CC 114)**

**Pleurotus hybrid (CC 201)**

**Pleurotus hybrid (CC 200)**

**Agaricus bisporus**

**DW: Dry weight;**

**I Retention time (R.T)=5.787; II R.T=11.773; III R.T=3.829; IV R.T=7.339;**

Data expressed as mean ± standard deviation (n=5); ANOVA and Fisher’s LSD Test at 5% significance level; Common superscripts between rows represent no significant difference between mushroom samples.
Animal Study

Balb/c mice
(7 weeks of age, 20 ± 2 g, n=120)

Group I - Control

Group II- Carcinogen treated

Phosphate Saline Buffer (PBS) only

N-methyl, N-nitrosourea (MNU) at 50 mg/kg body weight (i.p.)

Treatment Period of 3 months

Pleurotus sajor-caju

Agaricus bisporus

Group III
Dose (mg/kg b.w.)

III  150 + MNU (i.p.)

IV  300 + MNU (i.p.)

V  450 + MNU (i.p.)

VI  600 + MNU (i.p.)

VII  600

Group VIII

VIII  150 + MNU (i.p.)

IX  300 + MNU (i.p.)

X  450 + MNU (i.p.)

XI  600 + MNU (i.p.)

XII  600

Blood Sample

Mice Liver DNA

Haematological Analyses

Histological Analyses

Laser Raman Spectroscopy

Animal Study
Diets high in nitrostable foods cause cancer

- high levels of nitrates used in food preservation are carcinogenic

- Examples of foods **naturally** high in nitrates:
  
  *Fish, oysters, mussels, crab, lobster, Chinese cabbage, some leafy vegetables, Cigarette smoke, Beer & wine, Cheese, luncheon & sausage meats, Canned foods*
  
  *A possible reason why Asians have high rates of stomach & mouth cancers?*

Example: **N-methyl-N-nitrosourea (MNU)**

MNU causes several cancers in animal models. It targets the **liver** in mice
The liver/body weight ratio is highly indicative of tumour presence

Liver:Body Weight Ratio (%)

Liver:Body weight ratio for the 12 treatment groups Data expressed as mean ± standard deviation (error bars) (n=5); ANOVA and LSD at 5% significance; Similar superscripts on the mean values represent no significant differences between the treatment groups.
Morphological changes in mice and liver, and H&E stained liver sections from PBS, MNU, MNU+ME₁ 300mg/Kg and ME₂ 450mg/Kg groups after 3 months supplementation.

**PBS-treated mice**
- A

**MNU-treated mice**
- D

**MNU + ME₁ 300mg/kg**
- G, H, I

**MNU + ME₂ 450mg/kg**
- J, K, L

- Smooth and even growth of hairs in normal mice
- Healthy liver
- Pachy skin and uneven shedding of hairs
- H&E stained liver section: Nucleo-cytoplasmic ratio (cells appearing leaky), enlarged vacuolated hepatocytes, altered cell structure
- Extract Protective effect:
  - Reduction in hair loss
  - Reduction in lesions
  - Cell architecture almost comparative to PBS
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Morphological changes in mice and liver, and H&E stained liver sections from PBS, MNU, MNU+ME₁ 300mg/Kg and ME₂ 450mg/Kg groups after 3 months supplementation.
Healthy liver of Balb/c mice

Micronodular lesions in liver of MNU-treated mice

Histopathology of liver tissue

Reduction in lesions and mushroom protective effects (MNU + 300 mg/kg Mushroom A extract)

Reduction in lesions and mushroom protective effects (MNU + 450 mg/kg Mushroom B extract)

ONGOING Molecular Mechanisms Works

University of Seoul, South Korea
Laser Raman Spectroscopy

MNU acts as an alkylating agent reacting with nucleophillic nitrogen, oxygen atoms in bases and DNA phosphate groups to create mutagenic lesions.

The region 1200–1600 cm\(^{-1}\) (assigned to purines and pyrimidines) corresponds to nucleic bases which are prone to any type of alkylation by MNU.

Mushroom protective effect was confirmed by Raman spectroscopy where, the MNU-DNA interaction as evidenced by an intense peak at 1254 cm\(^{-1}\) was normalised and was not apparent in any of the mushroom-treated DNA samples.

Increased formation, repair and persistence of DNA adducts

Inflammation and elevated levels of inflammatory cytokines (IL-1b, IL-6)

Creating a micro-environment conducive for the survival and development of cancer cells.

Continuous exposure to MNU
Alkylation at adenine bases, resulting in a strong interaction between MNU and DNA structure.
Modulation of hepatocarcinogenesis in N-methyl-N-nitrosourea treated Balb/c mice by using mushroom extracts

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Prospects

USA: Commercial Production of *Agaricus bisporus*

Use of hallucinogenic mushrooms in Mesoamerica

- 500 B.C.
- 900 A.D.

1880

2016

2020

300 edible mushroom species identified
20 fold increase in mushroom production
Medicinal mushrooms and their derivatives - Clinical trials

Mauritius?
Still not meeting local demand, high imports

Scope for increasing cultivation
Production of active extracts

Cheap source of protein with ease of home production

Scientific Data on Mauritian mushrooms
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