

M U S H R O O M S

The New Superfood



M U S H R O O M S

The New Superfood

FOREWORD BY JANE CLARKE, NUTRITIONIST

We've always known that mushrooms are tasty, versatile and satisfying. They've been part of our staple diet for years. However, while some foods, such as broccoli and tomatoes are well known for their health properties, it seems that white mushrooms have been overshadowed, especially by their more exotic cousins, such as shiitake and oyster, which have been revered by herbalists for centuries.


But a recent study from America's Pennsylvania State University, led by Prof. Robert Beelman, has now allowed white mushrooms to take centre stage as the new superfood, after researchers discovered that they are a prime source of a powerful antioxidant L-Ergothioneine.

It was this research which led the Mushroom Bureau to commission myself and Sarah Schenker to compile this report, examining a whole raft of scientific studies from around the world into the nutritional value and health benefits of white mushrooms, *Agaricus bisporus*, and chestnut mushrooms (syn. *A. brunnescens*). This species accounts for 95 per cent of UK sales.

As a nutritionist I already knew that mushrooms were a valuable part of the diet, being a good source of B vitamins and essential minerals potassium, selenium, copper and phosphorus, as well as being low in calories, fat and sodium.

But new research, summarised in this report, is suggesting that mushrooms, or substances extracted from mushrooms, may have the potential to help fight cancer and heart disease. More research needs to be done in this area, but it makes powerful reading.

So whether you eat them grilled for breakfast in the morning, toss them into stir fries, add them to pasta sauces, serve them as a kebab on the summer BBQ, or simply pile them onto toast, there's never been more reason to include mushrooms in your diet.



OVERVIEW

White mushrooms, the variety most commonly found in the supermarkets, may have been overlooked as a superfood because they have been somewhat in the shadow of the exotic mushrooms, which are much better known for their medicinal properties. However, not only does the nutritional value of white mushrooms (*Agaricus bisporus*) and brown mushrooms (syn. *A. brunnescens*) compare favourably with the exotic mushrooms such as shiitake and oyster (*Lentinus edodes* and *Pleurotus* spp.), they also contain biologically active compounds that may help to prevent the occurrence, and aid the treatment, of chronic diseases including heart disease and various cancers (1), although further research is required in this area. This is especially true of brown strains of mushrooms like the portobellos, which are harvested when they are fully-mature with open caps resulting in a higher fibre and solids content. Compared with exotic mushrooms, *A. bisporus* mushrooms are significantly better sources of riboflavin and minerals potassium, selenium, and copper and comparable as sources of protein and vitamins thiamin, niacin and folate. Mushrooms count towards the 5-A-DAY target and are low in energy (calories), fat and sodium (salt), making them a valuable food commodity in the UK diet, where concern has never been more paramount. They are a versatile ingredient that can be easily added to many dishes and they can make a nutritious addition to meals, as their high water and fibre content makes them filling and satisfying, while their rich vitamin and mineral content can make an important and significant contribution to nutritional intake and overall health.

INTRODUCTION

Over 2,500 different mushrooms grow in the wild around the world. This report focuses on the nutritional composition and potential health benefits of the *A. bisporus* species, which includes the white mushrooms (button mushrooms, closed cup mushrooms, open cup mushrooms and large flat mushrooms) and the brown mushrooms (also called chestnut, champignon marron, crimini or portabello mushrooms). It summarises, with accompanying references, some of the key research projects from around the world.

A. bisporus is the most extensively cultivated mushroom in the world, accounting for 38% of the world production of cultivated mushrooms and 95% of UK sales.

Cultivated mushrooms are readily available in either fresh, frozen or canned preparations, however they do not home-freeze successfully. They are often a popular ingredient in many ready prepared foods such as pizzas, casseroles and salads.

Mushrooms are considered part of the fruit and vegetable food group and each serving (80g is about 14 baby buttons, or four large closed cup mushrooms, or a large flat or portabello mushroom, or a handful of sliced mushrooms) counts towards the 5-A-DAY target.

Mushrooms share some of the benefits of fruits and vegetables in that they are low in energy, and are virtually free of fat and sodium. *A. bisporus* mushrooms are a source of fibre and are fairly rich in vitamins and minerals. They contain an especially high amount of B vitamins and potassium. In addition, they contain other substances that may have potential health benefits and play a role in the prevention of serious diseases.

UK CONSUMPTION OF MUSHROOMS

The Expenditure and Food Survey conducted by DEFRA (2) has shown that the average consumption of mushrooms is currently about two and half times higher than in 1975; over recent years consumption levels have been fairly stable (Table 1).

Table 1: UK household consumption of mushrooms

	Adjusted National Food Survey			Expenditure and Food Survey			
	1975	1985	1995	2000	2001-02	2002-03	2003-04
Grammes per person per week	14	22	36	37	37	35	36

MUSHROOM CONTRIBUTION TO FRUIT AND VEGETABLE INTAKE AND THE 5-A-DAY PROGRAMME

The 5-A-DAY programme is a government initiative to encourage people to eat more fruit and vegetables. Products are individually assessed for inclusion and may then be labelled as part of the programme. All fruit and vegetables including fresh and canned mushrooms are counted towards the target, as are those used in food products such as soups or pizzas.

Household consumption of fruit and vegetables, although slowly rising as people's awareness of the health benefits of eating fruit and vegetables increases, has not yet reached the 5-A-DAY target. Current intakes amongst adults equates to an average of 4.1 portions per person per day but these portions include all fruit juice and baked beans (2). Most children are also consuming only between 2 and 3 portions of fruit and vegetables per day. Moreover, some population groups have very low intakes e.g. young men who average an intake of only 1-2 portions per day.

The increase has been driven mainly by higher consumption of fresh fruit and fruit juices. Consumption of fresh green vegetables and processed vegetables has been falling. However, consumption of non-green fresh vegetables, which includes onions, carrots, cucumbers and mushrooms, has been rising.

NUTRITIONAL COMPOSITION OF MUSHROOMS

The nutritional value of mushrooms depends on their chemical composition. Their high water content means that fresh mushrooms contain very little fat or carbohydrate and are low in energy (calories). They do, however, contain some protein (and can be a useful source for vegans) and significant quantities of B vitamins, including thiamin (B1), riboflavin (B2), pyridoxine (B6), niacin, and folate and also some vitamin C. Mushrooms are also a good source of minerals including iron, potassium, phosphorus,

magnesium, copper, manganese and selenium (table 2).

Table 2: Nutrient content of cultivated *Agaricus bisporus* (3,4)

	Per 100g*	UK DRV** (males 19-50 yrs)	% DRV	UK DRV (females 19-50 yrs)	% DRV
Energy (kcal)	13	2500 (GDA***)	0.52	2000 (GDA)	0.65
Energy (kJ)	55	10460	0.52	8368	0.65
Protein (g)	1.8	55.5	3.0	45.0	4.0
Fat (g)	0.5	95 (GDA)	0.52	75	0.67
Polyunsaturates (g)	0.3	-	-	-	-
Monounsaturates (g)	Tr	-	-	-	-
Saturates (g)	0	30 (GDA)	0	25	0
Carbohydrate (g)	0.4	-	-	-	-
Sugars (g)	0.2	-	-	-	-
Starch (g)	0.2	-	-	-	-
Fibre (g)	1.1	18	6.1	18	6.1
Calcium (mg)	6.0	700	0.86	700	0.86
Phosphorus (mg)	80.0	550	14.5	550	14.5
Magnesium (mg)	9.0	300	3.0	270	3.3
Sodium (mg)	5.0	1600	0.19	1600	0.19
Potassium (mg)	320	3500	9.0	3500	9.0
Chlorine (mg)	69.0	2500	3.0	2500	3.0
Iron (mg)	0.6	8.7	6.9	14.8	4.0
Zinc (mg)	0.4	9.5	4.2	7.0	5.7
Copper (mg)	0.72	1.2	60.0	1.2	60.0
Selenium (µg)	9.0	75	12.0	60	15.0
Iodine (µg)	3.0	140	2.1	140	2.1
Vitamin B1 (mg)	0.09	1.0	9.0	0.8	11.2
Vitamin B2 (mg)	0.31	1.3	23.8	1.1	28.2
Niacin (mg)	3.2	17	18.8	13	24.6
Vitamin B6 (mg)	0.18	1.4	12.8	1.2	15.0
Vitamin B12 (µg)	0	1.5	0	1.5	0
Folate (µg)	44.0	200	22.0	200	22.0
Vitamin C (mg)	1.0	40	2.5	40	2.5
Vitamin A (µg)	0	700	0	600	0
Vitamin D (µg)	0	-	-	-	-
Vitamin E (mg)	0.12	4	3.0	3	4.0

*100g of mushrooms is approximately 10 medium sized mushrooms
 **DRV = Dietary Reference Value (some of these values are different from EU RDAs which are used for labelling purposes)
 ***GDA = Guideline Daily Amount

FIBRE (OR NON-STARCH POLYSACCHARIDE)

Mushrooms are a valuable source of fibre, both insoluble (cellulose, lignin, chitin) and soluble, the main constituents of which are β -glucans and chitosans (5). There has been a lot of research interest in the β -glucans due to their potential anti-tumour effects (1). Most clinical evidence for anti-tumour activities comes from the commercial polysaccharides isolated from shiitake (*L. edodes*) and maitake (*Grifola frondosa*) mushrooms (6,7). In fact, Lentinan, a β -glucan polysaccharide from *L. edodes*, has been approved for

clinical use in Japan where many of these studies have been conducted (6). The mechanism(s) by which polysaccharides in whole mushrooms and isolated mushroom compounds might exert anti-tumour effects has been reviewed and the evidence indicates that it may be via enhancement of the numbers and/or functions of cells involved in the immune system including macrophages, natural killer cells, and various T cells (8). Whilst β -glucan concentrations are low in *A. bisporus* mushrooms regardless of raw or cooked state or stage of maturity (9), these are still a source of insoluble fibre, which is beneficial for gastrointestinal health.

IRON

Mushrooms provide small, but nutritionally important, amounts of iron, about 1 mg per 100g. Unlike many vegetable sources of iron, mushrooms do not contain phytates, which reduce the body's ability to absorb iron. The bioavailability of the iron in mushrooms is therefore high and up to 90% of the iron present can be absorbed (10). However, it is important to be aware that ultimately absorption will depend on what other foods the mushrooms are eaten with. For example, if they are eaten as part of a salad or with assorted vegetables, varying amounts of phytates will be present.

SELENIUM

Selenium, an essential trace mineral, functions largely through its association with proteins in the body, known as selenoproteins. Several selenoproteins defend against oxidative stress, a process that has been implicated in the development of many chronic diseases including heart disease and cancer. Selenium is the active centre of glutathione peroxidase, an essential enzyme in the body's defence against oxidative damage.

Mushrooms accumulate selenium based on their growing medium. Mushrooms provide more selenium than other foods in the fruit and vegetables food group and can be a source of this essential mineral for vegetarians. The average selenium content for *A. bisporus* mushrooms is 7.2 μ g, providing 12% of the RNI (60 μ g) for adult females per serving (80g).

ANTICANCER ACTIVITY

Selenium has received increasing attention as a possible cancer preventive trace mineral, possibly through antioxidant protection and/or increased immune function. The anticancer activity of selenium has been shown in laboratory animals and cell lines. There is also evidence from human studies to suggest that selenium may reduce the incidence of cancer when taken in higher doses. This includes large prospective studies such as the US Physician's Health Study (11) and the Netherlands Cohort Study (12), which both observed an inverse association between selenium status and prostate cancer. Intervention trials have also shown benefit with selenium in reducing cancer, specifically in the liver, prostate, colon and lung, with the greatest benefits in those with lowest selenium status (13,14).

An important consideration when evaluating the results of studies on the effects of selenium on cancer and other health conditions is the form of selenium and the seleno-compound present. Different active forms of selenium may be more effective (15), so information about the individual seleno-compound is important to assess potential health benefits. More research is needed to understand better the chemical species and metabolic activity of selenium in foods and to identify the specific form of selenium in mushrooms. Ongoing trials, such as the Selenium and Vitamin E Cancer Prevention Trial (SELECT) (16), will also help to clarify selenium's role in reducing cancer risk. Concern has been expressed, however, about falling intakes of selenium in some European countries including the UK.

POTASSIUM

Potassium's role as an essential mineral is well established. Potassium helps maintain normal heart rhythm, fluid balance, muscle, and nerve function. The Dietary Approaches to Stop Hypertension (DASH) Trial demonstrated that an eating pattern which was rich in fruits and vegetables, and low fat dairy products, provided benefits for blood pressure (17) and blood cholesterol levels (18). This diet contained substantial amounts of potassium, fibre and calcium and was low in fat and sodium.

The RNI for potassium is 3500mg for both male and female adults. The 2004 National Diet and Nutrition Survey (18) showed that average daily intake as a

percentage of the RNI ranged from 81% and 67% for men and women aged 19 to 24 years respectively. Furthermore, a significant proportion of women, 19%, had intakes below the lower RNI (LRNI). This is a cut-off intake value below which is almost certainly not enough to meet the requirement for most people. Mushrooms may be an under recognised source of potassium. A. bisporus mushrooms provide about 300mg potassium per serving and can help consumers increase their intake of this important nutrient.

B VITAMINS

Mushrooms contain significant quantities of several B vitamins, including thiamin (B1), riboflavin (B2), pyridoxine (B6), niacin, and folate. Table 3 lists the functions of these vitamins. Folate is particularly important for women who are pregnant, as low folate status is associated with increased risk of neural tube defects. Folate, pyridoxine and riboflavin are also involved in the metabolism of the amino acid homocysteine. Elevated levels of homocysteine have been linked with increased risk of heart disease and stroke and the most common cause of raised levels of this amino acid in healthy populations is folate insufficiency (20). The National Diet and Nutrition Surveys have shown poor folate status in some young women and older people and poor riboflavin intakes and status have been demonstrated in people of all ages (19). Eating mushrooms can help to boost intakes of these important vitamins, particularly as they are seldom boiled (B vitamins are lost when cooked in boiling water).

Table 3: Functions of B vitamins

Vitamin	Function
Thiamin (B1)	Needed for the metabolism of carbohydrate, fat and alcohol.
Riboflavin (B2)	Plays an essential role in the release of energy from carbohydrate, protein and fat.
Niacin	Involved in cell respiration and the metabolism of carbohydrate, protein and fat.
Pyridoxine (B6)	Plays an essential role in the metabolism of protein.
Folate	Needed for the regeneration of cells including blood cells and intestinal cells.

ANTIOXIDANTS

Plant-based foods generally are considered important sources of antioxidants in the diet. Antioxidants help

protect cells from the potentially damaging physiological process known as "oxidative stress" (damage to healthy cells or DNA by unpaired electrons known as free radicals). Oxidative stress is thought to be associated with the development of chronic diseases including cancer, heart disease, conditions of ageing including neurodegenerative diseases such as Parkinson's and Alzheimer's disease.

There are a variety of plant antioxidants with different chemical structures. There are the antioxidant nutrients such as vitamins C, E, beta-carotene and the trace element selenium (found in mushrooms) for which there are Dietary Reference Values (DRVs). However, there are thousands of other bioactive compounds in foods that have antioxidant activity but are not classified as "nutrients." These "non-nutrient antioxidants" include phenolic compounds (found in mushrooms) (1). These secondary metabolites in plants contribute to their colour or taste, or in some way function for the plant's benefit to attract pollinators or detract predators. There are no DRVs for these "non-nutrient" antioxidants.

Researchers led by Prof. Robert Beelman at Pennsylvania State University in the US have found that white button mushrooms contain high levels of the antioxidant L-Ergothioneine (21). L-Ergothioneine is a powerful antioxidant that scavenges free radicals such as superoxide, hydrogen peroxide and singlet oxygen and protects the cells' DNA from damage. The researchers found that just a handful of white button or brown mushrooms provides 5mg of the L-Ergothioneine, 12 times more than in wheatgerm and four times more than chicken livers, the previously top-rated foods containing L-Ergothioneine. L-Ergothioneine is very stable to heat and therefore will be present in cooked mushrooms.

Further in vitro experiments using mushroom extracts have shown them to suppress oxidation of fats (22), and also to expel peroxides and free hydroxyl radicals (23). The antioxidant capacities of mushrooms are enhanced by the presence of vitamin C, phenol amino acids and selenium protein.

The total antioxidant capacity of some different mushrooms is shown in table 4. There are various methods to measure a food's antioxidant activity against specific oxidative radical species. The ORAC assay

measures the oxygen radical absorbance capacity of a food and ranks it according to its score.

Table 4: Antioxidant capacity of selected mushrooms by different assays

Mushroom Type	Antioxidant Assay and Value	Reference
Button mushrooms	DPPH 700 Trolox equivalents (TE)/100 grams	(24)
White button	ORAC 400 mmol Trolox equivalents (TE) / 100 grams.	U. S. Mushroom Council unpublished data from Brunswick Laboratories (25)
Crimini	ORAC 500 Trolox equivalents (TE) / 100 grams	U. S. Mushroom Council unpublished data from Brunswick Laboratories
Portabello	ORAC 400 Trolox equivalents (TE) / 100 grams	U. S. Mushroom Council unpublished data from Brunswick Laboratories
Oyster	ORAC 700 Trolox equivalents (TE) / 100 grams	U. S. Mushroom Council Unpublished data from Brunswick Laboratories
Shiitake	ORAC 200 Trolox equivalents (TE) / 100 grams	U. S. Mushroom Council Unpublished data from Brunswick Laboratories

The use of total antioxidant capacity assays and rankings in studying the role of foods in health is of growing interest. However, these in vitro methods used to evaluate antioxidant capacity of foods may not reflect in vivo antioxidant effects (22) and further work is needed to assess their impact in relation to disease prevention.

POTENTIAL HEALTH BENEFITS OF MUSHROOMS

ANTI-NEOPLASTIC PROPERTIES OF EDIBLE MUSHROOMS

In addition to their nutritional values, the constituents contained in mushrooms also have potential benefits for optimising health and reducing risk of disease. The anti-neoplastic properties (having the ability to block the formation of neoplasms - growths that may become cancerous) of mushrooms were first described by Lucas in 1957. He demonstrated that administration of extracts from the wild (cep) *Boletus edulis* mushrooms to mice suffering from cancer increased their chances of survival. Ever since, the potential anti-cancer properties

of all mushrooms have been investigated.

The anti-neoplastic properties of edible mushrooms are thought to be due to the presence of specific polysaccharides. Much of the research to date has focused on the group of polysaccharides known as β -glucans, and in particular one called Lentinan, isolated from *Lentinus edodes* (shiitake) mushrooms, which has been shown to have a very strong anti-neoplastic effect. This β -D-glucan is not toxic for neoplastic cells, but suppresses their development by stimulating the immune system. Lentinan locally stimulates T and B-lymphocytes to divide and differentiate, and also activates other cells, among them macrophages, granulocytes and mast cells (26).

However, recent evidence suggests that *A. bisporus* also contain high levels of substances with anti-cancer properties such as tyrosinase, aromatase inhibitors and other anti-tumour polysaccharides (see below). Ying et al. (27) showed that hot water extracts of *A. bisporus* mushrooms contained polysaccharides that could inhibit the proliferation of cancerous cells by up to 100 percent. Later, Kweon et al. (28) investigated extracts from 10 different mushrooms for anti-tumour activity and found that the *A. bisporus* mushroom extract exhibited the most potent anti-tumour activity in cancer-infected mice.

Another group of compounds present in mushrooms is lectins. Their anti-neoplastic properties are thought to be based on causing apoptosis (cell death) in neoplastic (cancerous) cells, but their effect mechanism is not as yet fully understood (29).

BREAST CANCER

Research using extracts from white button mushrooms has suggested that they may be a useful chemopreventive agent for breast cancer, as they have been shown to contain a substance that may suppress aromatase/oestrogen biosynthesis. Aromatase is an enzyme that converts androgens to oestrogen. Increased expression of aromatase in breast tissue is considered to be a risk factor for breast cancer. Chen and colleagues (30) found that of the seven vegetable extracts tested, mushroom extract was the most effective in inhibiting the activity of this enzyme. Animal studies have also been conducted using mushroom extract and demonstrated tumour-suppressing effects (27).

PROSTATE CANCER

A series of in vitro and in vivo experiments (31) have also been carried out to investigate the effects of white button mushrooms in relation to prostate cancer and suggested that they may play a chemo-preventive role. White button mushrooms have been found to contain phytochemicals that suppress two enzymes - steroid 5alpha-reductase and aromatase. Steroid 5alpha-reductase converts the hormone testosterone to a different form of the hormone known as dihydrotestosterone (DHT) and it is this form that has been shown to play an important role in the development of prostate cancer. The use of steroid 5alpha-reductase inhibitors (substances that block the conversion) has been found to decrease the incidence of prostate cancer. As mentioned earlier, aromatase is the enzyme that converts androgens to oestrogen. This enzyme is expressed in prostate cancer cells and has been suggested to play a role in prostate cancer.

Experiments involving cells treated with mushroom extract for 10 days revealed that white button mushroom extract has the ability to suppress the growth of hormone resistant prostate cancer cells (31). Experiments in mice also demonstrated that the mushroom extract decreased tumour size (31). Pathology results indicated that there was significant increase in apoptosis compared to the control mice that did not receive the extracts but instead received a placebo, as well as a decrease in cell proliferation (cell division). The researchers concluded that the intake of mushroom extract could reduce the incidence of prostate cancer.

CARDIOVASCULAR DISEASE

Mushrooms may be able to impact on cardiovascular disease risk through their ability to reduce blood cholesterol levels. The results of numerous studies indicate that mushrooms are a valuable source of lovastatin (32), which suppresses the activity of the main cholesterol synthesis enzyme, hydroxymethylglutaryl CoA reductase (HMG CoA reductase), and thus has a hypocholesterolaemic effect. Laboratory studies have also shown that the consumption of mushrooms has the potential to impact on cholesterol uptake from the diet, leading to a fall in the total blood cholesterol concentration and in the low-

density lipoprotein (LDL) fraction (often known as 'bad' cholesterol), without any change to concentration in the high-density lipoprotein (HDL) fraction (often known as 'good' cholesterol) (33). Studies have also found that because of the presence of a relatively large quantity of fibre in mushrooms, and particularly glucans (they increase the viscosity of the food content), and of chitin and chitosans, there is elevated excretion of bile acids and neutral steroids. In the acid medium of the stomach, the amine groups occurring in chitosan molecules take on a positive charge and bond with negatively-charged bile acid residues. The low pH means that chitosan and bile acid complexes become insoluble and are excreted from the system (33).

WEIGHT CONTROL

Research into mushrooms and their potential role in weight loss diets is currently underway. Findings by Kern (34) show that when compared to other isocaloric diets, a mushroom-based diet produced greatest loss of fat tissue.

Mushrooms are low in energy and low in fat, one 80g serving provides only 10 kcals and 0.4 g of fat. In addition, mushrooms' high water content (over 90 per cent) can contribute to a feeling of fullness, and low energy (calorie) density can help to promote weight maintenance.

Analysis of data from the NHANES study (35) calculated the energy and fat savings if males substituted a 4-ounce grilled portabella mushroom for a 4-ounce (120g) grilled beef burger every time that they ate a grilled beef burger for one year. According to the calculation, they would experience an annual energy saving of 18,400 kcals, or a potential weight loss of 5.3 pounds and a yearly reduction of 2,725 grams of fat, assuming they did not compensate by eating other foods.

Chitosans are used in slimming products, as they lower the absorption of lipids from food. Their capacity to reduce body weight has been demonstrated in studies performed on two groups of volunteers, each comprising 100 people on a low energy diet. In patients who had been administered two chitosan tablets for four weeks, a loss of over 7 kg surplus weight was observed, while in the control group the average weight loss was 3 kg (36).

SUMMARY

The most commonly cultivated white mushrooms (*A. bisporus*) are a valuable food commodity in the UK diet. They are low in energy, fat and sodium, while their high water and fibre content makes them a filling and satisfying component of a meal. In the current climate of rising rates of overweight and obesity, they are a useful and versatile ingredient that can easily be added to many dishes without adding much to the energy content. They can also contribute to the 5-A-DAY fruit and vegetable target. They are a source of numerous vitamins and minerals including some B vitamins, iron, potassium and selenium. In addition, they contain potent antioxidant substances with potential beneficial effects on health. Numerous scientific studies have indicated that the biologically active compounds contained in mushrooms may help to prevent the occurrence and aid the treatment of chronic diseases including heart disease and various cancers.

REFERENCES

- 1 Beelman RB, Royse D and Chikthimmah N (2003) Bioactive Components in *Agaricus Bisporus* (J. LGE) Importance of Nutritional, Medicinal, or Biological Importance. *Int. J. of Medicinal Mushrooms*, 5, 321-337.
- 2 DEFRA (2004) Expenditure and Food Survey.
- 3 McCance and Widdowson's *The Composition of Foods*. Sixth Edition.
- 4 DH (1991) *Dietary reference Values for Food Energy and Nutrients in the UK*. HMSO.
- 5 Sadler M. (2003) Nutritional properties of edible fungi. *British Nutrition Foundation Nutrition Bulletin*. 28, 305-308.
- 6 Borchers AT, Stern JS, Hackman RM, Keen CL, Gershwin ME. Minireview (1999) Mushrooms, tumors and immunity. *Proc Soc Exp Biol Med*. 221,281-293.
- 7 Wasser SP. (2002) Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides. *Appl Microbiol Biotechnol*. 60, 258-274.
- 8 Borchers AT, Keen CL, Gershwin ME. (2004) Minireview: Mushrooms, tumors and immunity: an update. *Proc Soc Exp Biol Med*. 229, 393-406.
- 9 Dikeman CL, Bauer LL, Flickinger EA, Fahey GC Jr. (2005) Effects of stage of maturity and cooking on chemical composition of selected mushroom varieties. *J. Agric. Food Chem*. 53, 1130-38.
- 10 Knoop M.: *Pilze. Bestimmen, Sammeln, Zubereiten*. (1997) Falken Verlag, Niedernhausen.
- 11 Li H, Stampfer MJ, Giovannucci EL, Morris JS, Willett WC, Gaziano JM, Ma J. A prospective study of plasma selenium levels and prostate cancer risk. *J Natl Cancer Inst*. 2004;96:696-703.
- 12 van den Brandt PA, Zeegers MPA, Bode P, Goldbohm RA. Toenail selenium levels and the subsequent risk of prostate cancer. *Cancer Epidemiol Biomark & Prev*. 2003;12 866-871.
- 13 Rayman 2005 Selenium in cancer prevention: a review of the evidence and mechanism of action. *Proc Nutr Soc*. 64,527-42.

- 14 Clark LC, Combs GF Jr, Turnbull BW et al. (1996) Effects of selenium supplementation for cancer prevention in patients with carcinoma of the skin. A randomized controlled trial. Nutritional Prevention of Cancer Study Group. *JAMA* 276, 1957-63.
 - 15 Whanger PD. (2004) Selenium and its relationship to cancer: an update. *Br J Nutr.* 91, 11-28.
 - 16 Klein EA (2004) Selenium and vitamin E cancer prevention trial. *Ann N Y Acad Sci.* 1031, 234-41.
 - 17 Obarzanek E, Sacks FM, Vollmer WM, Bray GA, Miller III, ER, Lin P-H, Karanja NM, Most-Windhauser MM, Moore TJ, Swain JS, Bales CW, Proschan MA. (2001) Effects on blood lipids of a blood pressure-lowering diet: The Dietary Approaches to Stop Hypertension (DASH) Trial. *Am J Clin Nutr.* 74, 80-9.
 - 18 Harsha DW, Sacks FM, Obarzanek E, Svetkey LP, Lin PH, Bray GA, Aickin M, Conlin PR, Miller ER 3rd, Appel LJ (2004) Effect of dietary sodium intake on blood lipids: results from the DASH-sodium trial. *Hypertension.* 43, 393-8.
 - 19 FSA (2004) National Diet and Nutrition Survey: adults aged 19-64 years. TSO.
 - 20 British Nutrition Foundation Task Force report (2005) Cardiovascular Disease: Diet, Nutrition and Emerging Risk Factors. Blackwell Publishing.
 - 21 Beelman RB (2005) *Int. J. of Medicinal Mushrooms.* 5,321-337.
 - 22 Filipek J.(1992) The effect of the mushroom *Pleurotus ostreatus* on the lipid peroxidation of phosphatidylcholine liposomes. *Pharmazie.* 47, 393.
 - 23 Wu X, Beecher G, Holden JM, Haytowitz DB, Gebhardt S, Prior RL. (2004) Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. *J Agric Food Chem.* 52, 4026-4037.
 - 24 Miller HE, Rigelhof, R, Marquart L, Prakash A, Kanter M. (2000) Antioxidant content of whole grain breakfast cereals, fruits and vegetables. *J Am Col Nutr.* 19,312S-319S.
 - 25 ORAC Certificate of Analysis, Brunswick Laboratories 2000. Unpublished report to the Mushroom Council.
 - 26 Chihara G. (1987) Antitumor and metastasis – inhibitory activities of Lentinan as an immunomodulator: an overview. *Cancer Detect. Prev.* 1, 423–443.
 - 27 Ying J, Mao X, Ma Q, Zong Y, Wen H, Translated by Xu Y (1987) *Icons of medicinal fungi from China.* Science Press, Beijing, China. 307.
 - 28 Kweon M-H, Lim E-J, Sung H-C (1998) Studies on bioactive polysaccharides isolated from *Agaricus bisporus*. *Agri Chem Biotech.* 44, 60-66.
 - 29 Koyama Y., Katsuno Y., Miyoshi N., Hayakawa S., Mita T., Muto H., Isemura S., Aoyagi Y., Isemura M. (2002) Apoptosis induction by lectin isolated from the mushroom *Boletopsis leucomelas* on U937 cells. *Biosci. Biotechnol. Biochem.* 66, 784–789.
 - 30 Chen, Sheryl Phung, Gene Hur, Sharon Kwok, Jingjing Ye, Sei-Ryang Oh. Breast cancer prevention with phytochemicals in mushrooms. *Shiuan Proc Am Assoc Cancer Res.* 46, Abs. 5186.
 - 31 Sheryl Phung, Jingjing Ye, Gene Hur, Sharon Kwok, Ki Lui and Shiuan Chen. White button mushrooms and prostate cancer prevention. *Proc Am Assoc Cancer Res.* 46, Abs. 1580.
 - 32 Cheung P.C.K. (1996) Dietary fiber content and composition of some edible fungi determined by two methods of analysis. *J. Sci. Food Agric.* 72, 255–260.
 - 33 Endo A. (1988) Chemistry, biochemistry and pharmacology of HMG CoA reductase inhibitors. *Klin. Wochenschr.* 66, 421–427.
 - 34 Kern M. Role of Mushrooms Included In A Low Carbohydrate Diet On Weight Loss, Blood Lipids And Satiety. In press.
 - 35 Mushroom Council (2003) Mushrooms: more than just another fungus; analysis of NHANES III data.
 - 36 Muzzarelli R.A.A. (1999) Clinical and biochemical evaluation of chitosan for hypercholesterolemia and overweight control. In: *Chitin and Chitinases.* Eds.: Jollies P., Muzzarelli R.A.A. Birkhauser Verlag Basel, Switzerland, 293–304.
- Compiled for the Mushroom Bureau by Jane Clarke
BSc(Hons) SRD, researched by Sarah Schenker BSc SRD
PHD.

M U S H R O O M B U R E A U

6th Suite, 4th Floor, Regal House, 70 London Road, Twickenham, Middlesex, TW1 3QS

T: 020 8892 5665 F: 020 8892 5245

E: info@mushroom-uk.com W: www.mushroom-uk.com



Campaign financed with the assistance of the European Community