Utilization and management of mushroom production wastes into high value food and feed nutraceuticals.

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Abstract
During the production of mushrooms there is a great part of fresh waste byproducts which is currently underutilized and disposed of. These wastes refer to the removal of part of the stalks of the mushrooms as well as from the rejection of an important percent of the caps due to the fact that they do not comply to commercial standards and prototypes. The byproducts and wastes of the mushroom industries in Greece are estimated at about 400 tons per year. These wastes can be converted into high value food and feed nutraceuticals (β-glucans) which can be incorporated into various diets producing specified health care products for which there is a market demand as functional foods. It was in the last few decades that a diet – health message has evolved which initiated the development of functional foods. Therapeutic components such as β-glucans can be extracted from mushroom wastes which when incorporated into food and feed can render them to qualify as “Functional Foods”. Processing such agro-industrial wastes like mushroom wastes to produce nutraceuticals and functional foods will go a long way in providing food, nutrition and health security to our ever-increasing global population.

Keywords: β-glucans, mushrooms, functional foods, recycling, nutraceuticals

1. INTRODUCTION

Agro-industrial wastes represent a huge amount of industrial waste much of which is not properly utilized and upon disposal creates many problems with regard to environmental pollution. It is also a great burden in terms of waste management. Most of these wastes could be utilized with the use of appropriate clean technologies either to return safely to the place of their origin or to be recycled by physical or biological means for the production of high added value compounds.

One of these wastes is that of mushroom byproducts and wastes from mushroom industries. These wastes refer to the removal of part of the stalks of the mushrooms as well as from the rejection of a large percent of the caps due to the fact that they do not comply to commercial standards and prototypes. The quantity of the total byproducts and wastes of mushroom industries in Greece to be about 400 tons per year. At the same time, there are about 165 tones per week being created from substrate residues in which they grow. These wastes can be transformed into high value nutraceuticals such as β-glucans, with potential use in the food and feed industry [9]. This led to the growth of functional foods and nutraceuticals and created a “wholesome” movement in many countries worldwide. Mushrooms have been used for centuries as folk remedies but only lately they have been recognized as health promoting agents in the scientific literature (Dobisikova et al., 2013; Zhang et al., 2007). The immunomodulatory action of mushrooms is attributed to the presence of many bioactive compounds with β-glucans being the most important ones. The mode of action of medicinal mushrooms is accomplished with a number of specific receptor sites of the immune cells in many organisms to mushroom β-glucans (Hahn et al., 2006). In the feed industry, mushroom β-glucans are used for the stimulation of the animal’s immune system, avoiding the overuse of antibiotics and without adverse effects on the size and quality of animal production. For example, *Pleurotus ostreaus* β-glucans have been used in poultry feed where enhanced mucosal immunity was noticed (Muthusamy et al., 2013).

This paper deals with the utilization, monitoring and management of agroindustrial mushroom wastes of the most popular cultivated mushroom in Greece *Pleurotus ostreatus* into high value nutraceuticals, namely β-glucans and review some of the results from its incorporation into dairy products namely yogurt and cheeses.

2. MATERIALS AND METHODS

The concentration of β-glucans in mushrooms was calculated with the use of an enzymatic method Megazyme kit. ^{13}C CPMAS NMR spectra were recorded on a Bruker AVANCE III 600 NMR spectrometer (Karlsruhe, Germany) with a narrow bore magnet and 4-mm triple resonance probe. The samples were packed into 4-mm rotors and spun at 10 kHz. Beta-glucans were used in the form of paste during yogurt fermentation so that the final concentration of β-glucans in the yogurt was 0.3%, 0.4% or 0.5%. The yogurt enriched with β-glucans at all concentrations was then analyzed for physicochemical, textural, microbial as well as sensory quality parameters. The manufacture of feta-type cheese using low fat sheep milk (3%), with the addition of b-glucans also in the form of paste (0.4g glucan/100g cheese), was also carried out and similar quality parameters were tested.

3.RESULTS AND DISCUSSION

The waste byproducts from the Pleurotus *ostreatus* mushroom industry are rich in valuable nutrients such as protein, sugars and important metals. Furthermore, a large portion of carbohydrates in those wastes constitute glucans most of which are beta glucans. Figure 1 shows the solid-state NMR (CPMAS) spectra for *Pleurotus ostreatus* β-glucan. Two other β-glucans from *P. citrinopileatus* and Oat β- glucan reference are also depicted for comparison purposes. The graph shows high peaks in the region of 104 ppm which is indicative of the presence of beta-glucans in all three samples. It has a high molecular weight with polydispersity and broader MW distribution.

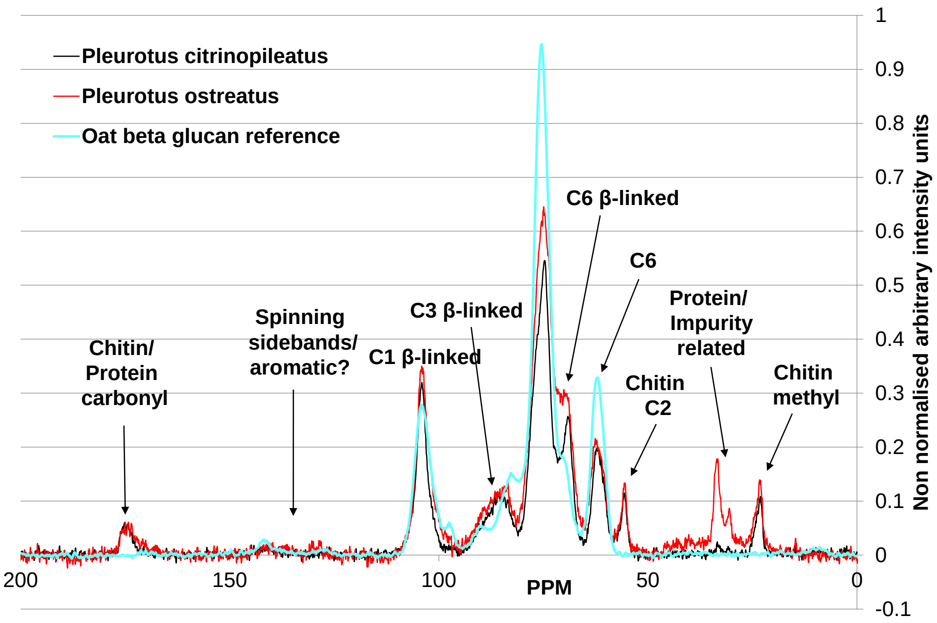

Figure 1. ^{13}C CPMAS NMR spectra for reference and extracted Mushroom β-glucans showing assignments of carbons assuming majority β-glucan carbohydrate present. Impurity signals also shown.

With regard to incorporation of β-glucan in yogurt it was shown that microbial population, pH, titrable acidity, ash and syneresis were not affected by the addition of different levels of glucan [20]. In general, yoghurt with 0.3% β-glucan exhibited comparable viscosity to the control while yoghurt with 0.5% β-glucan had the lowest viscosity compared to all other yogurts with the rest of β-glucan concentrations tested. Yogurt with β-glucans appeared to be better in flavour and texture compared to control (Kondyli et al. 2017).

Regarding similar experiments with low-fat feta-type cheese with β-glucans, no significant differences (P>0.05) were observed for pH, moisture, fat, salt, ash content, color and compression to fracture between cheese with β-glucans and control cheese, during ripening and storage [19]. However, cheese with β-glucans showed lower (P<0.05) hardness and fracturability compared to control. The addition of β-glucans did not affect (P>0.05) appearance and flavour scores and it was very much appreciated by the sensory panellists.

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