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Review paper

Effects of spent mushroom substrate on growth performance and meat characteristics of animals

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A B S T R A C T

After the production of mushrooms for human consumption, the used substrate remains (SMS — spent mushroom substrate). As much as five kilograms of spent substrate result from the production of one kilogram of mushrooms. Considering that the global production of mushrooms in the world has increased in recent decades, the amount of spent substrate has also increased sharply, which can lead to an unfavourable impact on the environment. The assumptions are that the amount of consumed substrate will exceed the value of 6 tonnes of SMS per km^2 of global land surface. This data points to the need for thinking and scientific research on how to reuse SMS. Various studies have established that SMS can first be used as a material from which to extract enzymes that remain after the production of mushrooms. Then, SMS can be used to grow one or two more production batches of mushrooms. Finally, SMS can be used as raw material for feed, as compost for plant growth and as biofuel. Research into the use of SMS as feed is particularly interesting, where its effect in the diet of various ruminant and non-ruminant species was examined.

1. Introduction

Fungi are eukaryotic organisms, present on Earth for at least 2.4 billion years (*Bengtson et al.*, 2017). They include about 120,000 species described so far (*Mueller & Schmit*, 2006). About 2000 species of edible mushrooms are known around the world (*Chuang et al*., 2020a), and are rich in proteins, fats, minerals, vitamins and are important as probiotics (*Finimundy et al.*, 2018). Common edible mushrooms belong to various genera, *Pleurotus*, *Agaricus*, *Lentinula*, *Flammulina* and others (*Chuang et al*., 2020b).

Edible mushrooms are grown on different substrates. Crop straw (wheat, oats, barley, rye, soybeans, rice), sawdust, tree bark and branches, sugar cane, soybean husks, cotton, peanut husks, grape seeds and by-products of the brewing and coffee industries are most often used to prepare the substrate and other materials rich in lignin and cellulose. From the aspect of animal nutrition, the best substrates are based on straw and grains of wheat, oats, barley and rye. After the production of mushrooms and the removal of the fruiting bodies, what remains is a spent substrate permeated with a network of fungal hyphae, rich in enzymes (cellulase, b-glucosidase, laccase, ligninase) and decomposed lignocellulose that animals can more easily use (than uncomposed lignocellulose) in the digestion process (*Adamović et al.*, 1998). The substrate can also contain relatively high levels of nitrogen, potassium, phosphorus and calcium and traces of iron and silicon (*Ball & Jackson*, 1995). It is signif-

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icant that the substrate does not contain mycotoxins, and the amounts of pathogenic bacteria and moulds are within the legal limits defined for the concentrations of harmful substances in feed (*Adamović et al.,* 1998). The chemical composition of SMS (73.6% neutral detergent fibre, 55.0% acid detergent fibre, 8.1% crude protein, 2.1% ether extract, 9.8% non-fibrous carbohydrate, and 6.4% crude ash) makes the substrate a potential source of feed (*Kim et al.*, 2007). SMS also contains phytogenic components, such as phenolic compounds and flavonoids, that significantly protect cells from free radical damage and can improve antioxidant capacity (*Tuzcu et al.*, 2008).

SMS contains a lot of moisture, so it is difficult to store it for a long time. The best and most cost-effective way to preserve it longer is ensiling, after combining it with other substrates that are rich in soluble sugars, primarily with the whole corn plant. Ensiled SMS, mixed with molasses and concentrate, is used by various animals in their diet (*Adamović et al.*, 1998). So far, many papers have been published on the use of SMS in the nutrition of poultry, pigs, sheep, goats, calves, cattle, heifers and cows, and its effect on the performance and characteristics of animal meat has been described.

2. Spent mushroom substrate (SMS) in animal nutrition

Traditional livestock feed includes straw and other agricultural residues that have low energy, protein and mineral content. Digestion of these feeds is hampered by the high amounts of hard-to-digest cell wall components, such as cellulose, hemicellulose and lignin (*Phillips*, 2004). Delignification of straw by chemical treatment is economically and environmentally unfavourable (*Lucio et al.*, 2020). However, fungi are very efficient decomposers of cell wall components, so these agricultural residues and lignocellulosic biomass can be degraded by biological processing using mushrooms (*Stamets*, 2000). By using mushrooms, agricultural waste is transformed into a valuable source of human food in the form of harvested mushrooms and as SMS, a source of feed. SMS is available in large quantities and its use as an alternative feed has been investigated. SMS can be included in amounts of 25–33% in the diet of adult animals, which have comparatively low nutritional needs, and in amounts of <15% in the diet of growing animals (*Van Wyk*, 2022).

The effects of SMS in the diet of calves were investigated. Spent wheat straw after the production of *Agaricus bisporus* was included in the calf diet (*Fazaeli et al.*, 2014). The results showed that this SMS, included in the pelleted diet, can be included in amounts of up to 15% and that the production performances of the calves were improved. *Kim et al.* (2011) also recommended that fermented sawdust after growing *Pleurotus ostreatus* can be used in calf diets at 10%, as it improved calf growth after weaning by 8%. Feeding dairy cows with silage prepared from green corn plants and SMS (80:20) in amounts of 4–5 kg per cow per day resulted in an increased concentration of milk fat compared to the control. This can be explained by a larger amount of cellulose, and therefore a larger amount of acetic acid, which is a precursor in the synthesis of milk fat. Studies have also shown that spent wheat straw after mushroom production can be used as a component in the diet of young heifers in amounts of 2–3 kg per heifer per day, if a smaller increase in body weight is desired (0.6–1.0 kg/ day). SMS can also be included in cattle nutrition in the amount of 2.5 kg (10% of dry matter in the meal). Growth was lower, but satisfactory, which certainly implies lower costs for food (*Adamović et al.*, 1998).

The influence of SMS in pig nutrition on growth performance, immunity and antioxidant capacity was investigated (*Boontiam et al.*, 2020). The pigs were divided into two groups, one the control, and the other supplemented with 2g/kg of SMS. The results showed that the group supplemented with 2g/kg of SMS had higher final body weight and higher daily gain, and there was no effect on daily feed intake, feed conversion rate, glucose and lipoproteins. Also, there were positive changes in immunoglobulin A, immunoglobulin G, total antioxidant capacity and glutathione peroxidase activity. The percentage of leukocytes and the concentrations of cholesterol and malondialdehyde decreased.

The nutritional value of SMS has also been investigated in the sheep diets (*Fazaeli & Talebian-Masoudi*, 2006). SMS resulting from the production of the mushroom *Agaricus bisporus* was included in different amounts (0% (control), 10%, 20%, 30%) in sheep feed. The results showed that the inclusion of 20% SMS did not affect the digestibility of dry matter, organic matter, crude fibre, acid detergent fibre or neutral detergent fibre, so the authors recommended SMS is used in this amount. Dietary supplementation with SMS in goat diets has also been studied. *Park et al.* (2012) found that in goats fed with 15% SMS supplementation for 6 weeks, the number of white blood cells and lymphocytes significantly increased compared to the control group.

The effect of SMS was also investigated on growth performance and meat characteristics of geese (*Chang et al.*, 2016). Three groups of geese were fed with different amounts of SMS (5% SMS, 10% SMS and 15% SMS) for 8 weeks. The results showed that there were no significant effects on the relationship between feed consumption and feed conversion rate. There were no significant effects on blood biochemical parameters either. The body mass of the group with 15% SMS was significantly lower than the control group, which was explained by the increased amount of coarse fibre in the feed which reduces the rate of digestion of nutrients. However, the group with 5% SMS stood out for extremely favourable sensory properties (meat taste and acceptability) as well as color, which has a favourable effect on consumer meat choice. It was recommended that 5% of corn in goose diet can be replaced with 5% SMS, which would significantly reduce feed costs, and the meat could have better sensory characteristics. Similar results were obtained by *Foluke et al*. (2014), who investigated the use of SMS in broiler diets as a substitute for wheat bran. Five groups of broilers used wheat bran and SMS as bran replacement at different concentrations (0% (control), 25%, 50%, 75% and 100%) for eight weeks. The results showed that feed intake increased equally in all groups. Body mass and feed conversion rate were significantly higher in the control and 25% SMS groups. However, the color and quality of breast, drumstick, back, neck and wing meat were equally acceptable in all groups of broilers, so it was concluded that SMS could replace wheat bran in broiler production. Other authors (*Chuang et al., 2020c*) also believe that 5% SMS dietary supplementation can be given to broilers because it improved the composition and color of the meat.

3. Conclusion

SMS is created after the production of edible mushrooms, and its annual production has been increasing in recent decades. There is a large body of research that shows that SMS can be used in animal nutrition. There is an opportunity to develop standard feed formulations that help the farmer (by reducing feed costs) and the mushroom grower (by helping with waste disposal). The confirmed nutritional value of SMS and its economic benefits in the form of reduced feed prices could be used to a greater extent in the future. Further studies and research are certainly needed in this area.

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