Characterization of different mushrooms powder and its application in bakery products: A review

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ABSTRACT
Bakery products such as bread, cookies, biscuits, and cakes are a large family of popular food products, consumed by a wide range of people all over the world, due to their varied tastes, relatively long shelf-life and low-cost. Enrichment of these products with vitamins, mineral, protein, polyphenols and fibres may be achieved by incorporation of rich sources. Powdered Mushrooms are one of these sources that have great potential. This paper reviews the effect of different mushrooms powder on the nutritional, rheological, physicochemical, textural and quality characteristics of the bakery products. Addition of mushroom powder contributes to the higher content of vitamins, mineral (calcium, potassium, magnesium, phosphorus, iron, copper, zinc and manganese), polyphenols, crude fibre and protein content in the bakery products. The crumb colour, physicochemical and textural properties of bread, cakes and biscuits were affected by the replacement of wheat flour with mushroom powder. According to sensorial analysis results, the 4–10% mushrooms powder in bakery products showed the best sensory properties.

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Introduction
Today, there is a health-conscious demand for convenient, health-promoting foods. Dried fruits and vegetables in the form of powders provide a means for producers to improve the health benefits of cereal products. Bakery products such as bread, cakes and biscuits are consumed all over the world and the enrichment of these products with the vitamin, mineral, polyphenols and fibres may be achieved through the incorporation of rich sources. Dried mushrooms are one of these sources, which have great potential (Figure 1). Rai and Arumuganathan studied the value-added products from the mushrooms. They have prepared various mushrooms powder value-added products like biscuits, soup powder, nuggets, noodles, candies, pickles and ketchup. Wan Rosli and Aishah reported that Pleurotus sajor-caju improves the nutritional profile/characteristics contents and maintains sensory properties of carbohydrate-based products. According to Aida, Shuhaimi, Yazid and Maaruf and Sanchez, over 200 species have been collected from nature and used for various traditional medical purposes. About 35 species have been cultivated commercially, and 20 are cultivated on an industrial scale. The most cultivated mushroom global is button mushroom (BM), followed by oyster mushrooms (OM), shiitake, wood ear mushroom, winter mushroom and straw mushroom. The BM (Agaricus bisporus) is the most widely cultivated and consumed mushrooms all over the world and it contributes about 40% of the total world production of mushrooms. OM (Pleurotus sajor-caju) is an excellent consumable grey mushroom described by a white spore print and gills attachment. 14.2% of the total world mushroom production is for OM, and it is ranked the second popular cultivated mushroom after the BM.
Mushrooms powder has a great potential to be used as an ingredient soon in various food industries, such as breakfast cereals and bakery such as biscuits, cakes and bread. Efforts have been made to utilize dried mushrooms in foods such as bread, biscuits, and cakes. Mushrooms powder can be used in bakery products for acquiring nutritionally valuable products which can be consumed by a wide group of consumers with almost every meal. The present study summarized the effect of dried mushrooms on the rheological, textural and physical properties and quality of bakery products.

**Producing mushroom powder**

Mushrooms are very perishable and the shelf life of fresh mushrooms is only about 24–48 h at ambient conditions. Therefore, they should be consumed or processed promptly after harvest. Drying is one of the significant preservation methods employed for storage of mushrooms and dried mushrooms are valuable ingredients in a variety of bread, cakes, biscuit, sauces and soups. As mushrooms are very sensitive to temperature, choosing the correct drying technique can be the key to a successful operation. Many studies were done to drying of mushroom by different drying methods such as hot air, vacuum heat pump, freeze-drying, infrared (IR)-vacuum, osmotic dehydration, fluidized bed, IR, and microwave. IR drying was used before or after freeze-drying of mushroom (shiitake) to decreases in the drying time, to improve the rehydration, and to better protect the aroma compounds and colour by Wang, Zhang and Adhikari. Their results demonstrated that the combination of freeze-drying (for 4 h) followed by IR drying keep 48% time compared to freeze-drying while keeping the quality of product at a satisfactory level. The application of IR drying also helps produce a more porous microstructure in dried shiitake mushrooms. Salehi, Kashaninejad and Jafarianlari studied the drying kinetics of combined IR-vacuum drying of BM slices. The effective moisture diffusivity ($D_{\text{eff}}$) of BM increases as power increases and range between 0.83 and $2.33 \times 10^{-9}$ m$^2$/s. The rise in IR radiation power has a negative effect on the colour change ($\Delta E$) of BM and with increasing IR radiation power, it was increased. The thermal conductivity and specific heat of mushrooms were reported by Shrivastava and Datta for a moisture range of 10.2 ± 89.7% (w.b.) and temperature range of 40–70°C. Both the thermal properties increased almost linearly with the increasing levels of input variables. The specific heat of mushrooms changed from 1.716 to 3.949 kJ/kg°C for the experimental range of variables studied. Far-IR drying characteristics of mushroom slices were studied by Darvishi, Najafi, Hosainpour, Khodaei and Aazdbakhchi. Drying curves demonstrated just a falling drying rate period. Their results show that the logarithmic model is the most suitable model for IR drying behaviour of thin-layer drying of mushroom slices. A third-order polynomial model was found to correlate the $D_{\text{eff}}$ with moisture content. The average $D_{\text{eff}}$ increased with increasing temperature and decrease in the moisture content of mushroom slices and varied from $8.039 \times 10^{-10}$ to $20.618 \times 10^{-10}$ m$^2$/s.
**Nutritional value and health benefits of mushroom powder**

Mushrooms are rich sources of nutraceuticals that are responsible for their antioxidant, antitumor and antimicrobial properties. Medicinal mushroom extracts were considered as important remedies for the prevention of many diseases for thousands of years especially in the oriental regions such as cancer, diabetic, heart diseases, atherosclerosis and cirrhosis.

The concentrations of elements varied between mushrooms and collection sites. Mushrooms alone contributed to the intake of arsenic and other elements which were below the provisional tolerable weekly intakes (PTWI) values due to the very low consumption of mushrooms in the diet. Rashid, Rahman, Correll and Naidu studied the arsenic and other elemental concentrations in mushrooms from Bangladesh. The mean concentrations (mg/kg) of As, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, and Zn in mushrooms were 0.51, 0.38, 0.28, 0.01, 13.7, 0.31, 11.7, 0.12, 0.28, and 53.5, respectively. Based on the dietary intake of mushrooms, the weekly intakes of As, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, and Zn from mushrooms for adults were 0.0042, 0.0030, 0.0024, 0.0001, 0.1125, 0.0019, 0.1116, 0.0011, 0.0023, and 0.4734 mg, respectively. Experimental data on the differences on contents in arsenic concentration in the dry biomass of mushrooms versus the fresh biomass are important to encourage off-season supply and consumption of dry mushrooms in meals. Llorente-Mirandes, Llorens-Muñoz, Funes-Collado, Sahuquillo and López-Sánchez examined the fate of total arsenic when cooking (boiling and gridding) the cultivated mushrooms species such as *A. bisporus, P. ostreatus* and *L. edodes*. Boiling of *A. bisporus, P. ostreatus* and *L. edodes* with double distilled water for 10 minutes (once the mushrooms had been cooked, the cooking water was removed) caused a decrease of total arsenic content in the product by 53%, 71% and 60% respectively.

Nutritional compositions and functional characteristics of *Pleurotus sajor-caju* (PSC) powder are presented in Table 1. Proximate analysis showed that PSC powder contains a low amount of moisture (7.04%) and fat (2.30%) but high levels in protein (22.41%), carbohydrate (60.47%) and ash (7.79%), resulting in 451.6 cal/g calorific value. High dietary fibre PSC powder can be used as an excellent food ingredient replacing refined powder or other traditional dietary fibre sources in making dietary fibre-rich health products.

Evaluation of amino acid and fatty acid profiles of commercially cultivated OM (*Pleurotus sajor-caju*) grown on gmelina wood waste was studied by Kayode, Olakulehin, Adedeji, Ahmed, Aliyu and Badmos. The sample was obtained and analyzed for fatty acid and amino acid profile on a dry weight basis (w.b.) using standard methods. The chemical score of the essential amino acid of the mushrooms, which ranged from 55.94% (methionine) to 150.31% (isoleucine), was comparable to standard dietary reference intake requirement. Fatty acid profile showed the presence of polyunsaturated (linolenic 29.54%, linoleic 11.6% and arachidonic 0.22%), monounsaturated (oleic 41.71%, palmitoleic 0.22% and erucic 7.09%) and some saturated (caprylic 0.92%, myristic 0.18%, palmitic 5.34%, margaric 0.21%, stearic 2.38%, arachidic 012%, behenic 0.25% and lignoceric 0.16%) fatty acid.

**Table 1. Nutritional compositions and functional characteristics of Pleurotus sajor-caju powder (mean ± SD).**

| Nutrients             | Concentration (%) | Functional characteristics | Values             |
|-----------------------|-------------------|-----------------------------|--------------------|
| Fat                   | 2.03 ± 0.02       | Water holding capacity (g/g)| 13.46 ± 0.28       |
| Moisture              | 7.04 ± 0.02       | Oil holding capacity (mL/g)| 8.52 ± 0.13        |
| Protein               | 22.41 ± 0.65      | Swelling capacity (mL/g)    | 19.49 ± 0.24       |
| Ash                   | 7.79 ± 0.41       | Emulsifying ability (%)     | 51.67 ± 0.25       |
| Carbohydrate          | 60.47 ± 0.51      | Emulsion stability (%)      | 95.37 ± 0.21       |
| Calorific value (cal/g)| 451.6 ± 2.7      |                             |                    |
| Sucrose               | 0.19 ± 0.00       |                             |                    |
| Total dietary fibre   | 56.99 ± 0.92      |                             |                    |
| Soluble dietary fibre | 8.21 ± 0.41       |                             |                    |
| Insoluble dietary fibre| 48.79 ± 0.90     |                             |                    |
| β-glucan              | 3.32 ± 0.13       |                             |                    |
**Physicochemical characteristics of mushroom powder**

Chemical composition of some fresh and dried edible mushrooms reported in Table 2. Besides their pharmacological features, the consumption of edible mushrooms is increased due to their nutritional value, related to high protein (20–40% dry basis), high vitamins and minerals, low fat, and are preferred due to their special flavor and aroma. The nutritional values of dietary mushrooms have been determined by Alam, Amin, Khan, Ara, Shim, Lee and Lee. The mushrooms were rich in proteins (20–25%) and fibres (13–24% dry basis) and contained a lower amount of lipid (4 to 5%). The carbohydrate and ash contents ranged from 37 to 48% (dry basis) and 8 to 13% (dry basis), respectively. Data of their study suggest that mushrooms are rich in nutritional value and mineral (calcium, iron, zinc, magnesium, manganese, selenium and arsenic) contents (Table 3).

**Incorporating in bakery products**

**Bread:** The enrichment of bread, biscuits and cakes with protein may be achieved through the addition of rich protein source. BM is one of the protein sources, which have great potential, due to their good and high-quality protein. Table 4 summarized the effect of dried mushrooms powder on the chemical properties of bakery products. With increasing in mushroom levels, the protein, fat, mineral and crude fibre content were increased.

Paratha flat bread, rice-porridge and conventional cake were formulated with dried OM powder by Aishah and Wan Rosli. Their results showed that the percentage of moisture, ash and protein of samples increased in line with the levels of OM powder used except for carbohydrate. Mushroom-based products received a better score on textural attribute compared the control sample. In cake,.

| Mushroom          | Moisture (%) | Protein (%) | Fat (%) | Ash (%) | Crude fibre (%) | Carbohydrate (%) | References |
|-------------------|--------------|-------------|---------|---------|-----------------|------------------|------------|
| Pleurotus sajor-caju (fresh) | 88.00 | 5.12 | 0.5 | 1.40 | - | 5.00 | [19] |
| Pleurotus sajor-caju (fresh) | 89.89 | 5.05 | 1.69 | 1.8 | - | 4.61 | [60] |
| Pleurotus ostreatus (fresh) | 88.8 | 4.82 | 0.74 | 1.06 | - | 4.58 | [32] |
| Pleurotus ostreatus (fresh) | 88.00 | 4.20 | 0.41 | 1.66 | - | 5.73 | [31] |
| Agaricus bisporus (fresh) | 91.02 | 3.26 | 0.19 | 0.78 | - | 6.46 | [61] |
| Pleurotus pulmonarius (fresh) | 89.17 | 1.78 | 0.15 | 0.62 | - | 9.02 | [61] |
| Agaricus bisporus (powder) | 6.8 | 32.5 | 1.6 | 7.5 | 9.2 | 42.4 | [22] |
| Agaricus bisporus (powder) | 6.30 | 23.91 | 4.6 | 9.39 | 42.34 | 55.8 | [61] |
| Agaricus bisporus (powder) | 4.38 | 33.25 | 1.29 | 6.98 | - | 64.21 | [61] |
| Pleurotus sajor-caju (powder) | 7.04 | 22.41 | 2.30 | 7.79 | 56.99 | 60.47 | [13] |
| Pleurotus sajor-caju (powder) | 11.0 | 12.37 | 1.80 | 5.78 | - | 69.05 | [19] |
| Pleurotus ostreatus (powder) | 10.6 | 15.7 | 2.66 | 7.04 | - | 64.1 | [61] |
| Pleurotus ostreatus (powder) | 9.04 | 13.02 | 2.39 | 6.95 | - | 68.06 | [31] |
| Pleurotus ostreatus (powder) | 10.13 | 11.03 | 2.92 | 6.90 | - | - | [31] |
| Pleurotus plumonarius (powder) | 8.60 | 36.00 | 1.90 | 7.60 | 7.90 | 38.00 | [61] |
| Pleurotus plumonarius (powder) | 4.88 | 30.30 | 1.10 | 13.21 | - | 76.11 | [61] |
| Pleurotus florida (powder) | - | 20.56 | 4.30 | 9.02 | 23.29 | 42.83 | [62] |
| Lentinus edodes (powder) | - | 22.8 | 2.1 | 6.0 | - | 64.4 | [64] |
| Volvariella volvacea (powder) | - | 28.0 | 3.3 | 1.0 | - | 50.3 | [65] |
| Auricularia auricular (powder) | - | 36.0 | 4.37 | 5.2 | - | 28.5 | [66] |
| Flammulina velutipes (powder) | - | 17.6 | 2.89 | 7.43 | - | 73.1 | [67] |
| Calocybe gambosa (powder) | - | 15.46 | 8.3 | 13.89 | - | 69.82 | [68] |
| Calocybe indica (powder) | - | 21.4 | 4.95 | 13.1 | 12.9 | 48.5 | [62] |

| Mushroom | Calcium (Ca) | Iron (Fe) | Zinc (Zn) | Magnesium (Mg) | Manganese (Mn) | Selenium (Se) | Arsenic (As) |
|----------|--------------|-----------|-----------|----------------|----------------|---------------|--------------|
| Pleurotus ostreatus | 35.9 | 55.54 | 26.56 | 16.39 | 2.85 | 0.011 | 0.1 |
| Pleurotus sajor-caju | 22.15 | 33.45 | 20.9 | 20.22 | 2.87 | 0.025 | 0.095 |
| Pleurotus florida | 33.7 | 43.2 | 16 | 13.4 | 2.7 | 0.013 | 0.083 |
| Calocybe indica | 20.65 | 56.25 | 12.86 | 12.82 | 1.64 | 0.013 | 0.54 |
sample panels prefer the cake added with 4% powdered OM as they gave higher scores for softness and flavour attributes. They are recommended that powdered OM can be considered to be applied in carbohydrate-based food products to improve nutrient ingredients and quality properties.

Addition of mushroom powders are a cost-effective way to increase protein content and nutritional properties in wheat bread. Fortification of wheat bread using mushroom powder (at three levels of 5, 10 and 15%) was studied by Mahamud, Shirshir and Hasan.\textsuperscript{[19]} The bread containing 5% powdered OM showed a considerably better result for texture and total acceptability. In the case of nutritional composition, the bread with 5% powdered mushroom was better than bread with no mushroom powder. Ulziijargal, Yang, Lin, Chen and Mau\textsuperscript{[20]} used 5% mushroom mycelia to replacement with wheat flour to make bread. They reported that the incorporation did not adversely influence bread’s texture and bread containing mycelium showed higher umami intensity than white bread. In addition, the incorporation may have beneficial health influences since the supplemented bread contains significant amounts of the ergothioneine and amino acids γ-aminobutyric acid.

Rheological characteristics and quality analysis results on bread and biscuits supplemented with powders of legume seeds or mushroom in ratios of 5, 10, and 15% was studied by Eissa, Hussein and Mostafa.\textsuperscript{[17]} Baking characteristics, colour and sensory analysis tests showed that 15% of wheat flour

| Bakery products | Mushrooms percent (flour basis) | Moisture (%) | Fat (%) | Protein (%) | Carbohydrate (%) | Fibre (%) | Ash (%) | References |
|-----------------|---------------------------------|--------------|--------|-------------|------------------|----------|--------|------------|
| Breads containing oyster mushroom | 0% | 17.3 | 9.10 | 9.46 | 62.50 | - | 1.63 | [19] |
| | 5% | 16.04 | 9.20 | 10.07 | 62.87 | - | 1.82 | |
| | 10% | 19.36 | 9.73 | 10.74 | 57.16 | 2.01 | - | |
| | 15% | 17.53 | 10.10 | 11.40 | 58.76 | 2.20 | - | |
| Breads containing oyster mushroom | 0% | 32.60 | 1.69 | 7.96 | 56.42 | 0.51 | 0.90 | [21] |
| | 5% | 32.04 | 1.70 | 9.68 | 54.37 | 0.89 | 1.32 | |
| | 10% | 31.92 | 1.68 | 11.07 | 52.63 | 1.20 | 1.56 | |
| | 15% | 32.26 | 1.80 | 12.75 | 49.67 | 1.54 | 1.93 | |
| | 20% | 31.08 | 1.89 | 13.24 | 48.89 | 1.98 | 2.11 | |
| | 25% | 32.17 | 1.72 | 14.62 | 46.47 | 2.48 | 2.64 | |
| Sponge cakes containing button mushroom | 0% | 18.40 | 23.34 | 5.95 | 51.50 | - | 0.81 | [5] |
| | 5% | 19.59 | 23.25 | 6.52 | 49.71 | - | 0.94 | |
| | 10% | 19.27 | 23.26 | 7.09 | 49.26 | - | 1.12 | |
| | 15% | 19.65 | 23.19 | 7.66 | 48.18 | - | 1.32 | |
| Cakes containing oyster mushroom | 0% | 17.43 | 17.0 | 7.1 | 57.95 | - | 0.52 | [32] |
| | 5% | 15.37 | 17.8 | 8.57 | 57.28 | - | 0.98 | |
| | 10% | 16.19 | 18.9 | 9.49 | 54.93 | - | 0.49 | |
| | 15% | 18.51 | 19.5 | 10.91 | 50.4 | - | 0.68 | |
| | 20% | 19.06 | 19.98 | 11.42 | 48.68 | - | 0.86 | |
| Cakes containing oyster mushroom | 0% | 18.43 | 15.10 | 8.70 | 57.09 | - | 0.68 | [31] |
| | 5% | 16.04 | 16.63 | 9.60 | 56.71 | - | 1.02 | |
| | 10% | 22.19 | 17.90 | 10.23 | 49.10 | - | 0.53 | |
| | 15% | 19.02 | 18.50 | 14.68 | 50.04 | - | 0.76 | |
| | 20% | 20.06 | 18.93 | 13.36 | 46.81 | - | 0.84 | |
| Biscuits containing oyster mushroom | 0% | 1.37 | 22.68 | 6.50 | 68.59 | 3.37 | 0.86 | [15] |
| | 4% | 1.34 | 22.75 | 6.91 | 68.20 | 6.19 | 0.88 | |
| | 8% | 1.25 | 22.90 | 7.43 | 67.47 | 8.62 | 0.95 | |
| | 12% | 1.16 | 23.08 | 7.85 | 66.92 | 9.84 | 1.00 | |
| Biscuits containing 5% oyster mushroom | 3.97 | 17.36 | 11.07 | 65.62 | 0.48 | 1.50 | [24] |
| Biscuits containing oyster mushroom | 0% | 4.79 | 21.71 | 13.04 | 61.63 | 2.10 | 1.52 | [6] |
| | 5% | 4.98 | 20.58 | 13.41 | 61.58 | 2.16 | 1.87 | |
| | 10% | 6.71 | 20.51 | 13.46 | 60.95 | 2.27 | 2.81 | |
| | 20% | 8.35 | 20.39 | 15.47 | 58.11 | 2.56 | 3.47 | |
| | 30% | 9.63 | 19.05 | 15.55 | 58.62 | 2.93 | 3.58 | |
| Biscuits containing shiitake mushroom | 10% | 6.54 | 20.16 | 10.55 | 66.06 | 13.0 | 1.52 | [25] |
| Biscuits containing button mushroom | 10% | 2.5 | 14.8 | 8.4 | 71.8 | 1.1 | 1.4 | [22] |
| Biscuits containing oyster mushroom | 10% | - | 22.15 | 9.20 | 65.22 | 1.74 | 1.69 | [23] |
could be replaced with germinated legumes and mushroom powders and still providing high protein content and good quality of bread and biscuit samples. Increasing the percentage of added raw and germinated legumes powders and mushroom powders to wheat flours, the values of lightness, redness, yellowness, chroma, hue angle and browning indexes values slightly increased in all fortified bread and biscuits. In addition, dough development time, per cent of water absorption and weakening of dough increased but dough stability and mixing tolerance index decreased in the raw and germinated legumes powders sample.

**Cake:** Natural fibres exhibit profits of improved texture and firmness in foods and improved sensorial attribute such as texture and flavour that have positive consumer acceptance.\(^{[69,70]}\) According to sensorial analysis results, addition of 4–10% mushrooms powder in bakery products showed the best sensory properties (Table 5). The addition of dried mushrooms powder to the sponge cake formula changed the physicochemical properties of the cakes.\(^{[5,29]}\) Incorporation of fibres in cakes decreased the volume and increased the firmness, but the extent of modification was dependent on the fibre content of powders.\(^{[71]}\)

Salehi, Kashaninejad, Asadi and Najafi\(^{[5]}\) studied the rheological characteristics of cake batters and textural, physicochemical properties, and sensory attribute of sponge cake prepared with BM powder. Increasing the level of BM powder significantly increased the protein and ash content \((p < .05)\). The viscosity of cake batters, and volume, springiness, and cohesiveness values of baked cakes raised with addition BM powder levels but the density, consistency, hardness, gumminess, chewiness and crumb colour indexes \((L^* \text{ and } b^* \text{ values})\) of cakes showed a reverse trend. The sensory evaluation results showed that cake with 10% mushroom powder was rated the most acceptable. In another study, the effect of BM powder on viscoelastic properties of sponge cake using stress relaxation test was investigated by Salehi and Kashaninejad.\(^{[30]}\) Their results showed that with increasing substitution of mushroom powder initial force and balance force values were decreased. The parameters of Peleg-Normand model include \(k_1\) and \(k_2\) decreased with the time that indicating

| Bakery products | Mushrooms | Scientific name | Used percent of powder (flour basis) | Suggested percent of powder Substitution (flour basis) | Nutrients being fortified | References |
|-----------------|-----------|-----------------|--------------------------------------|-----------------------------------------------------|---------------------------|------------|
| Bread           | Oyster mushroom | *Pleurotus sajor-caju* | 5, 10 and 15% | 5% | Increased moisture, ash, fat, protein and carbohydrate content. | ![19] |
| Bread           | Oyster mushroom | *Pleurotus plumonarius* | 0, 5, 10, 15, 20 and 25% | 10% | Improved the nutritional quality of bread. | ![21] |
| Sponge cake     | Button mushroom | *Agaricus bisporus* | 0, 5, 10 and 15% | 10% | Increased protein and mineral content. | ![5] |
| Conventional cake | Sponge cake | Oyster mushroom | *Pleurotus sajor-caju* | 0, 2, 4 and 6% | 4% | Increased moisture, ash and protein content. | ![14] |
| Sponge cake     | Oyster mushroom | *Pleurotus eryngii* | 3, 5 and 7% | 5% | Increased ash and protein content. | ![29] |
| Cake            | Oyster mushroom | *Pleurotus ostearus* | 0, 5, 10, 15 and 20% | 15% | Improved colour, flavour and texture of cakes. | ![32] |
| Cake            | Oyster mushroom | *Pleurotus ostearus* | 0, 5, 10, 15 and 20% | 15% | Improved colour, flavour and texture of cakes. | ![31] |
| Biscuits        | Shiitake mushroom | *Lentinus edodes* | 0 and 10% | 10% | Increased protein and mineral content. | ![25] |
| Biscuits        | Oyster mushroom | *Pleurotus sajor-caju* | 0, 4, 8 and 12% | 8% | Increased protein, crude fibre and ash content. | ![15] |
| Biscuits        | Button mushroom | *Agaricus bisporus* | 0, 5, 10, 15 and 20% | 10% | Increased protein, crude fibre, carbohydrate and mineral content. | ![22] |
| Biscuits        | Oyster mushroom | *Pleurotus sajor-caju* | 0, 5, 10, 20 and 30% | 5% | Increased protein, crude fibre and ash content. | ![6] |
| Biscuits        | Oyster mushroom | *Pleurotus plumonarius* | 5, 10 and 15% | 5% | Increased protein, fat, mineral and crude fibre content. | ![23] |
a reduced elasticity of the cake over time. The cakes show solid viscoelastic behaviour and by increasing replacement, total reduced forces ($F_1 + F_2 + F_3$) of the generalized Maxwell model decreased that reflects the increase of elasticity. The Maxwell model has more efficient to an evaluation of viscoelastic properties of sponge cake with mushrooms powder. Sheikh, Kumar, Islam and Mahomud\cite{31} studied the effect of mushroom powder on the quality of cake and have specified that 15% addition level has best acceptability.

**Biscuits:** Mushroom is favoured due to its delicious flavour and low calorific content. Also they contain a high content of protein, fibre and other essential nutrients.\cite{16} The influence of partial substitute of wheat flour at three levels including 10, 20 and 30%, with mushroom powder (Pleurotus plumonarius) and sweet potato flour on the chemical characteristics and sensory attribute for produced biscuits, was investigated by Ibrahim and Hegazy.\cite{23} Their results showed that biscuits processed from wheat flour supplemented by 10 or 20% of mushroom powder/sweet potato flour blend exhibited a good sensory attribute and better acceptability. Currently, research has been performed on the using of mushroom powder as a source of dietary fibre in wheat-based foods.\cite{11,15} Ng, Robert, Ahmad and Ishak\cite{15} determine the effects of OM powder addition at three levels of 0, 4, 8 and 12% on the nutritional values, thermal characteristics, pasting properties, in-vitro starch digestibility, microstructure, in-vivo glycaemic index and sensorial properties of biscuits. Interestingly, appreciable amounts of total dietary fibre (56.99%), insoluble dietary fibre (48.79%), soluble dietary fibre (8.21%) and β-glucan (3.32%) were detected in the OM powder. Elevated incorporation levels of OM powder decreased the pasting viscosities and starch gelatinisation enthalpy value of biscuits. Increasing the level of the OM powder resulted in a significant increase in the level of protein, ash, total dietary fibre and β-glucan, with the 12% OM biscuit recorded the highest nutritional values. The restriction of starch hydrolysis rate markedly reduced the glycaemic index of biscuits. The addition of 8% OM powder in biscuits (glycaemic index = 49) reported an effective way of developing a nutritious and low glycaemic index with desirable sensorial properties. Singh, Sindhu, Sindhu and Yadav\cite{25} improved nutrient, physicochemical and sensorial properties of biscuits using shiitake mushroom powder. Their results showed that crude protein content of biscuits increases from 5.74 to 10.55% with addition shiitake mushroom powder.

Biscuit is high in carbohydrates, calorie and fat but low in vitamin, fibre and mineral compound which make it unhealthy for daily use. Also, biscuits have only about 6–7% protein. This may be achieved through mixing of protein-rich ingredients from mushroom as a fortification of biscuits.\cite{24,72} Farzana and Mohajan\cite{24} studied the effect of incorporation of soy flour to wheat flour on nutritional properties and sensory quality of biscuits containing OM (Pleurotus ostreatus). Nutrient composition and sensory characteristics of biscuit containing OM powder were investigated by Bello, Oluwamukomi and Enujiugha.\cite{6} Their results showed that the protein content increased from 13.0% in the control sample (100% wheat flour) to a range of 13.4% – 15.5%. In the biscuits, ash raised from 1.5% to a range of 1.9–3.8% and fibre content increased from 2.1 to 2.2–2.9%. While crude fat and carbohydrate contents of biscuits reduced from 21.7 to 19.1–20.6% and 61.6 to 58.6–61.6%, respectively. Also with increasing levels of mushroom powder, the thickness, mean, diameter, spread ratio and weight were increased. The result of the mineral analysis showed that the potassium and sodium were the main mineral elements in the biscuit samples and the mineral (calcium, potassium, magnesium, phosphorus, iron, copper, zinc and manganese) composition increases with the level of OM addition (Table 6).

| Mushroom level (flour basis) | Calcium | Sodium | Potassium | Magnesium | Phosphorous | Iron | Copper | Zinc | Manganese |
|-----------------------------|---------|--------|-----------|-----------|-------------|------|--------|------|-----------|
| 0%                          | 12.10   | 62.68  | 40.63     | 7.02      | 12.45       | 1.68 | 0.04   | 0.08 | 0.06      |
| 5%                          | 22.03   | 36.15  | 51.63     | 8.05      | 21.45       | 2.15 | 0.04   | 0.53 | 0.06      |
| 10%                         | 27.06   | 41.20  | 63.05     | 10.04     | 45.64       | 2.38 | 0.05   | 0.62 | 0.07      |
| 20%                         | 38.05   | 54.31  | 143.05    | 13.04     | 54.62       | 2.45 | 0.12   | 0.95 | 0.17      |
| 30%                         | 47.05   | 65.92  | 154.07    | 14.00     | 64.25       | 2.89 | 0.13   | 1.16 | 0.18      |
Sulieman, Zhu, Peng, Hassan, Obadi, Siddeeg and Zhou studied functional, rheological, physicochemical and quality properties of composite gluten-free dough and biscuits supplemented with fermented and unfermented BM polysaccharide flour. Their result showed that fermented and unfermented Agaricus bisporus polysaccharide flours formulation contained the highest nutrients in terms of protein, dietary fibres, amino acids and minerals among the composite gluten-free biscuit formulations.

**Conclusion**

Bakery products such as bread, cakes and biscuits are consumed all over the world and the fortification of these products with protein, polyphenols and fibres maybe get through the additions of rich fibres and polyphenols sources. Addition of mushroom powder contributes to the higher content of vitamins, protein, mineral, crude fibre and phenol content in the products. The addition of mushroom powder to the bakery formula changed the physicochemical, textural properties of the products. The volume of cakes increased with increase in mushroom powder levels. Based on sensorial analysis results, the 4–10% mushrooms powder in bakery products showed the best sensory properties. With increase in mushroom powders levels in bakery products, the calcium, potassium, magnesium, phosphorus, iron, copper, zinc and manganese content were increased.

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