Review of chemical research work on edible fungi in Hungary

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Edible fungi are ubiquitous organisms which are known to serve as a food of value for human beings and also for domestic animals. Though the nutritional value of the fungi has been known for long time, chemical research work dealing with the chemical composition and biochemical systems of edible fungi has been done only in the last decades. This holds true of Hungary as well, where the main part of the research work on the chemistry of mushrooms takes place in two institutes, the Department of Biochemistry and Food Technology of the Technical University at Budapest and the Central Food Research Institute. At the Technical University following topics have been dealt with: investigation of the carbohydrate components of mushrooms; polyacrylamide gel electrophoresis of mushroom proteins and investigation of the distribution of proteins between pileus and stipe; investigation of the distribution of some enzymes in the fruiting body; investigation of enzyme activities by histochemical methods; thin layer chromatography of mushroom lipids.

In the Central Food Research Institute the preservation of mushrooms by ionizing radiation was studied and it was established that the keeping quality of the cultivated mushroom may be increased through this procedure. A pilot plant scale process was elaborated. - The favourable effect of the ionizing radiation may be explained by its influence on the hormone system and investigations have been made with plant hormones. It was stated that cytokinins influence the opening of the pileus. The greatest part of the cytokinins is to be found in the gills, but during storage this level decreases. Further research work on the cytokinins of fungi is going on.

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In the field of the investigation of edible fungi chemical, biological and technological research is done in Hungary. The main part of the research of the chemistry of mushrooms takes place in two institutes, the Department of Biochemistry and Food Technology of the Technical University at Budapest and the Central Food Research Institute Budapest. At the Technical University following topics have been dealt with: investigation of the carbohydrate components of mushrooms; polyacrylamide gel electrophoresis of mushroom proteins and investigation of the distribution of proteins between pileus and stipe; investigation of the distribution of some enzymes in the fruiting body; investigation of enzyme activities by histochemical methods; thin layer chromatography of mushroom lipids.

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amide gel electrophoresis, and it was established that soluble species. Certain differences could be established between the distribution of the proteins in pileus and stipe (Törley 1978).

Amino acids and peptides

Free amino acids of cultivated mushroom and of two wild growing species: Russula cyanoxantha and Leccinum scabrum were determined. The greatest part of the protein-forming amino acids occur in these fungi in the free state. The glutamic acid, aspartic acid and proline content is markedly high. $\beta$-alanine, $\gamma$-aminobutyric acid and 2,4-diaminobutyric acid were also identified.

Beneath the amino acids peptides were also isolated from some species (A. bisporus, Leccinum scabrum), occurring regularly in the fruiting bodies. Determination of the structure is in progress.

Investigation of the possibility to extend the storage life by irradiation

The storage of harvested mushrooms forms a serious problem because they are prone to rapid spoilage. Extension of the storage life of mushrooms has been the subject of investigation in many countries. In Hungary the possibility of using radiation treatment for the extension of their storage life was investigated (Kovács et al. 1968, Kovács & Van 1969, 1971-1971).

In agreement with results of experiments abroad our investigations have shown that ionizing radiations are suitable to improve substantially the storage stability of mushrooms. The effect of irradiation depends to a large extent on the storage conditions subsequent to treatment.

It has been found under cold storage conditions (5°C, 70-90% rel. humidity, storage time of 13 days) that by using a 25 krad dose the ratio of opening of the pileus could be reduced with c. 55-60%. The effect can be increased if the radiation treatment is carried out with 100 krad (Fig. 1). When storage is taken place at room temperature (16-18°C, 65% RH) an irradiation dose of 300 krad is necessary. The samples given this kind of treatment can be stored for 5-6 days without loss of value, while the storability of the untreated samples is only one day.

There is a smaller loss of weight in irradiated samples than in the untreated ones. It was a general observation that irradiated mushrooms taste better than untreated ones and that the treatment had no immediate effect on the colour, odour, flavour or texture of the mushrooms. Radiation treatment is immediately followed by a slight brownish discoloration which, however, does not increase on further storage, in contrast to the intensive browning of non-irradiated controls. The tendency to browning is observed mainly when irradiation is carried out with an electron accelerator or at room temperature. Ionizing radiation did not cause deterioration of the organoleptic properties of the mushrooms, on the contrary it promoted preservation of aroma and flavour.
Investigation of substances that affect the growth of mushrooms

At present the biology of mushrooms in the post-harvest period is being studied. Hormonal control is the subject of investigations.

Substances affecting the growth of mushrooms have not been sufficiently investigated. It was noted already at the beginning of the century that the pileus contained one or more substances which affected the growth of the stipe. These substances were not found to be identical with the auxin-type substances in higher plants.

Although auxin was found to be present in the gills as well, this was not, however, responsible for the growth of mushrooms. Probably ripening of the mushroom and the opening of the pileus is determined by the mutual effect of hormones, and with knowledge of this mutual effect light will be thrown on the role of auxins.

The cytokinins are mainly responsible for the inhibition of aging of plants. The question arises whether cytokinins are present in mushrooms and how the opening of the cap is affected by them. Miller (1967) and Crafts & Miller (1974) reported having detected zeatin and zeatin riboside in various mushroom varieties. This cytokinin activity was determined by soy callus test.

The method of Letham & Williams (1969) was used to extract cytokinin from *A. bisporus*. In the course of the thin-layer chromatographic qualitative analysis zeatin and N6-dimethylallyladenine (DMAA) were identified.

The flesh and the gills were examined separately and it was found that the change as a function of storage time occurred mainly in the gills. Therefore in subsequent experiments gills were mostly used.

Mushrooms freshly picked were treated with the extract of gills in the following manner: on a tray containing 500 ml of gill extract 15 mushrooms were placed with their stipe immersed 1 cm deep into the extract. The tray was placed in a thermostat of 19-20°C temperature and 97-99% RH. The mushrooms were incubated for 25-40 h and during this time the diameter of the pileus, the opening formed and the height of the whole body were regularly measured.

Fig. 1. Effect of ionizing radiation on the preservation of *Agaricus bisporus* at 5°C (70-90% RH, storage time of 13 days). Co60 γ source (0, 25, 100 and 300 krad).

So far the quality of mushrooms has been established by morphological and sensory methods.

Fig. 2 shows the frequency distribution of openings at four different points of time. The concentration of the extract changed from 1 to 60 g/l. The opening is understood to mean the distance between the stipe and the edge of the pileus. The opening was expressed as percentage of the initial diameter of the pileus. Twenty to sixty mushrooms were measured in each experiment and the average of three experiments is illustrated in the figure. A significant difference was observed in the frequency distributions as obtained at the four points of time with mushroom extracts of different concentrations. Evaluation was carried out by multi-sample $X^2$-test. It was established that mushroom extracts prepared from 30-50 g gills per litre inhibited substantially the opening of mushroom pilei.

On the basis of preliminary experiments four characteristic opening ranges were established:

- group A consisted of mushrooms with closed pilei.
- group B consisted of mushrooms with 11-21% opening, corresponding to 4.1-8 mm distance;
- group C consisted of mushrooms with 22-28% opening, corresponding to 8.1-12 mm distance;
- group D consisted of mushrooms with 29-38% opening, corresponding to 12.1-16 mm distance (Fig. 2).

Fig. 3 shows the distribution of mushrooms according to the four groups as a function of storage time. Diagram A shows the frequency of mushrooms with closed pilei as a function of time. It can be seen that the opening is a function of the concentration of the extract. In graphs B and C the frequency of openings is nearly constant, while in graph D the frequency increases significantly with the observation period. (Opening inhibiting extract concentrations form exceptions).

In Fig. 4 the influence of mushroom extracts of different concentrations upon the opening of the pileus, is illustrated. Opening ranges were grouped according to groups A, B, C and D, as described above. Measurements were carried out after incubation periods of 20 and 42.5 h. The fact that the pilei are influenced according to the optimum curve points to hormonal control (Fig. 4).

Since the pilei openings were strongly inhibited by the gill extracts it seemed desirable to purify the extract in order to be able to detect its chemical composition.
Fig. 2. Frequency distribution of openings at four different points of time (A, B, C, D are characteristic opening regions; 0, 11-21, 22-28 and 29-38%). *** = very highly significant difference.

**BUTANOLIC PHASE**

18 hours

\[ x^2 = 37** \]

20 hours

\[ x^2 = 58.28*** \]

38.5 hours

\[ x^2 = 135.28*** \]

42.5 hours

\[ x^2 = 189.02*** \]

- \( \times \) control
- \( \circ \) 3
- \( \triangle \) 9H gills extract
- \( \triangleleft 30\)
- \( \diamond \) 60
Fig. 3. Distribution of mushrooms according to the four groups as a function of storage time (A, B, C, D are characteristic opening regions, cf. Fig. 3).

**BUTANOLIC PHASE**

A

B

C

D

E

F

incubation times (hours)

x control
○ 5 %cell susp. extract
▼ 50
▼ 20
▲ 5
△ 0
Fig. 4. Influence of mushroom extracts of different concentrations upon the opening of the pileus (A, B, C and D are characteristic opening regions, cf. Fig. 3).

References
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