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Irradiation of fresh mushroom fruit-bodies

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Already in the year 1967 Staden referred on the experiments with irradiation of fresh mushroom fruit-bodies with ionizing radiation in order to prolong their storage period and to maintain their fresh appearence: the caps remained closed, the surface didn't change and the flavor after cooking was found to be equal or even slightly better. The influence of gamma rays in dosages 50-800 krad's was investigated more profoundly in the years 1970-1975 and the best results were obtained with 200 krad's. The number of epiphytic and phytopathogenic micro-organisms on the fruit-bodies surfaces decreased, the protease activity in the tissues of the stored irradiated fruit-bodies declined; the inhibition of respiration was observed, and fruit-bodies weight losses during the storage were lower. The test results showed that the fruit-bodies irradiated with dosages up to 200 krad's were hygienically unobjectionable. On degustation the irradiated mushrooms were found more flavorful by the majority of 100 degustating specialists than the non-irradiated fruit-bodies. On mushroom purchase the customers prefer the irradiated mushroom fruit-bodies. The irradiated mushroom can be stored reliable at the temperature of 5° C for 15 days, at 10° C for 10 days, and at 15° C for 7 days.

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Mushrooms start to deteriorate immediately after having been picked. The quality of harvested mushrooms is influenced by several factors, such as temperature, high moisture, desiccation, etc. At room temperature mushrooms deteriorate quickly: the stipes grow longer, tha caps open and the dark gills appear. Later the fruit-bodies become brown and useless. Normally mushrooms are stored at low temperatures, at 0-2° C, and at air humidity of approximately 90%. The cooling time of mushrooms is rather long because they have an intensive respiration and so produce much heat as well as CO_2 and moisture (14 000 kcal/1 000 kg/24 hours at 20° C; Langerak 1971). A quicker and better method is vacuum cooling (Barnard 1974). The disadvantages of these cooling methods are loss of fresh weight and acceleration of quality deterioration of the fruit-bodies after removal from cool storage. The explanation of this lies in the rapid physiological change occurring in the stored mushroom (in the enzyme activity and mannitol concentration; Goodenough 1976). It was also mentioned that although mushrooms maintain an acceptable appearance in chilled storage there is loss of flavour.

Already in 1964 and 1967 Staden referred on the experiments with irradiation of fresh mushroom fruit-bodies with ionizing radiation in order to prolong their storage time and maintain their fresh appearrance. In his experiments the caps of the irradiated fruit-bodies remained closed, the surface did not change, and the flavour after cooking was found to be equal or even slightly better. The following experiments have demonstrated that mushrooms packed in closed cartons and irradiated after harvesting give the optimum quality without the necessity for extreme cooling (Langerak 1971).

Experiments with irradiation of mushroom fruit-bodies with ionizing radiation were made in Czechoslovakia in 1970-1975, too.

The preliminary experiments have confirmed the results of Staden's explorations. Most of the mushrooms irradiated after cropping with a dosages of 100-300 krad Co^{60} did not open their caps and kept their original appearance even on the 10th day of storage at the temperature of 15° C. Very good results were obtained with 200 krad. The dose of 50 krad had a low effect; the dosages 400-800 krad deteriorated the appearance of the fruit-bodies.

In further experiments the irradiated fruit-bodies were stored at various temperatures and moistures. It was found that at temperatures of 22-29° C and the higher air moisture the total quality of the mushrooms became worse faster, their surface being on the 7th day only a little harmed, however.

The mushroom fruit-bodies artificially contaminated by a spore suspension of *Verticillium malthousei* Ware were covered with the mycelium of this parasitic fungus on the 5th-7th day of incubation at 22° C. After contamination and gamma rays irradiation (250 krad) of mushrooms the disease either did not appear at all or seemed to be reduced to an imperceptible occurrence of spots. The same results were obtained after irradiation of mushrooms artificially contaminated by *Mycogone perniciosa* Magnus. The disease index was reduced in both cases in connection with

the radiation dose used (Staněk et al. 1970).

The epiphytic micro-organisms colonizing the surface of the mushroom fruit-bodies (especially *Pseudomonas* spp., *Mucor* spp., *Trichoderma* spp., *Aspergillus* spp.) were affected by irradiation, too. The number of epiphytic bacteria increased during the storage of the check fruit-bodies at a temperature of 25° C quickly and at 8° C slowly. After irradiation (100-400 krad) their number was significantly lower. The germination of spores of *Aspergillus fumigatus* which may produce aflatoxin was inhibited by application of the dose of 300 krad gamma rays of Co^{60} (Staněk & Urban 1974).

It was found that the loss of weight of mushrooms stored at temperatures of 8° C and 20° C was less after the application of gamma rays than that of non-irradiated fruit-bodies. The loss depended on the dose applied: the higher the dose, the lower the loss of weight. By means of a respirometric method it has been determined that the respiration of tissues from mushroom fruit-bodies was influenced by radiation (Staněk et al. 1972b).

In the later stage of the research the effect of gamma rays on the activity of proteases in mushroom fruit-bodies was investigated in order to explain partly the mechanisms of the irradiation effects.

The activity of the proteases (gelatinases) in the tissues of fresh mushroom fruit-bodies was relatively high in the gills (lamellae) and very low in the centre of the cap (pileus). During the storage period the activity of the proteases increased in all of the tissues of check mushrooms quickly; after irradiation the changes were slow and not so striking (Staněk et al. 1972a).

The tests carried out by the Czechoslovak health authorities showed that the mushroom fruit-bodies irradiated with dosages up to 200 krad were hygienically unobjectionable. On degustation the irradiated mushrooms were found more flavourful by the majority of 100 degustating specialists than the non-irradiated fruit-bodies. On experimental mushroom purchase the customers preferred the irradiated mushroom fruit-bodies.

It may be concluded that irradiated mushrooms can be stored at the temperature of 8° C for 15-20 days, at 10° C for 10-15 days, and at 15° C for 7-10 days without damaging their quality. Attention must be paid to packing because the irradiation does not protect the fruit-bodies against influence from outside (Langerak 1971).

All of the conclusions of Staden (1967) have been verified. After irradiation of mushrooms, 1) the shelf life can be extended markedly, 2) the caps remain closed, 3) taste and flavour are preserved, 4) the colour of the surface remains whiter, 5) less loss in quality is caused by the action of fungal infection.

It was found that the extended shelf life was obtained not only by the surface "pasteurizing effect" of gamma rays but also by their physiological effect on the mushroom itself, by influencing proteases which had an important role in autolytic processes.

N. Barnard from W. Darlington & Sons Ltd. in Great Britain, in discussing the methods of shelf life extension, wrote in 1974: "A lot of work has been carried out in recent years to try and prolong the very short shelf life of mushrooms. These include very sophisticated methods such as ionizing irradiation and freezing with liquid gases down to simply putting the mushrooms into a cool store as soon as possible after picking".

There are also other ways of prolonging the shelf life of fresh mushrooms: storage of pre-packed mushrooms in an optimal gas composition (Sveine et al. 1967, Nichols & Hammond 1974, etc.), vacuum cooling, etc. The irradiation of fruit-bodies belongs to the most effective processes. The main disadvantage of this method is the restricted possibility of its application. It can be useful only in the case the irradiation station is not far from a large mushroom production centre. This seasonal gamma ray treatment of mushrooms in summer can be combined with the irradiation of various agricultural products such as onions, potatoes, etc. in other seasons.

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