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Effect of storage conditions on the quality of cultivated mushrooms (Agaricus bisporus (Lange) Sing.) *

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Abstract

A number of quality factors were studied during storage of cultivated mushrooms (*Agaricus bisporus*) at 2°C in controlled atmospheres. A concentration of 15% CO_2 and 1.5-2% O_2 and an atmosphere with a continuous flow of nitrogen retarded cap expansion and stipe elongation, while 10% CO_2 retarded only cap expansion. Controlled atmospheres suppressed the growth of some microorganisms. The toughness of mushrooms stored in a normal atmosphere at 2°C markedly decreased during storage, while 10% CO_2 and nitrogen atmosphere did not influence toughness as compared to initial mushrooms. The acceptability value of mushrooms in controlled atmospheres was lower during 13 days of storage as compared to normal atmosphere. Normal atmosphere appeared to keep whiteness of mushrooms longer than did other treatments.

INTRODUCTION

After harvesting, the quality of mushrooms deteriorates quickly at room temperature: the stipes grow longer, the caps grow larger and finally open and dark gills appear. Further, the product becomes brown and tough. The degree of whiteness is one of the most important quality factors associated with mushrooms and generally the whitest mushrooms obtain the highest price. Mushrooms with L values (based on Hunter Color and Color Difference Meter) below 69 would not be acceptable to the normal consumer and those with L values below 80 would not be acceptable at the wholesale level (Gormley, 1975b; Gormley and O'Sullivan, 1975). Temperature has a marked effect on the rate

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of deterioration of mushrooms. Cameron and Chappel (cited by Gormley, 1975b) have shown that buttons can be stored succesfully for periods up to 7 days at 1°C with a subsequent shelf life of 2-3 days. Lutz and Hardenburg (1968) showed that mushrooms keep in prime condition for 5 days at 0°C.

According to Gormley (1975a), only one treatment (5 days at 1°C + 2 days at 20°C) gave mushrooms with whiteness values above the wholesale acceptability level after 7 days. Several techniques have been introduced which effectively delay the deterioration of harvested fruits and vegetables. Among these techniques, controlled atmospheres involving a modification of the storage atmosphere by lowering the oxygen and/or increasing the carbon dioxide levels with strict temperature control have shown the most promise. Seveine et al. (1967) indicated that low O_2, increased CO_2 and low temperature, separately, prevented the opening of mushroom caps.

Controlled atmosphere storage prolonged the shelf-life of *Agaricus bisporus* (tan strain) if the O_2 concentration was 9% or CO_2 concentration was 25 or 50% (Murr and Morris, 1975). It was observed that at 5% O_2, maximal stimulation of pileus expansion and stipe elongation occurred. Levels of CO_2 above 5% markedly inhibited mushroom growth. However, 5% CO_2, while inhibiting cap expansion, stimulated stipe elongation. Since Murr and Morris (1975) used a tan strain for their experiments, they did not report color deterioration during storage which is one of the most important quality factors for white strains, but probably less important for tan strains of *Agaricus bisporus*.

Subsequently, it has been shown that gas permeable plastic films could increase the storage life of mushrooms (Badran et al., 1969; Nichols and Hammond, 1973). Analysis of the internal atmosphere of the pre-pack indicated that after 24 h, a rough equilibrium concentration of CO_2 and O_2 was established and the mean concentration was dependent on the type of film (Nichols and Hammond, 1973). At 18°C the atmosphere inside the pre-pack prevented opening of the caps and in combination with prevention of water loss by the film, slowed down deterioration of the mushroom. Concentrations of CO_2 much above or below 10-12% were associated with increased internal browning. At 2°C, overwrapping generally caused slight external browning of the pileus. The observation of the fresh mushrooms which were kept in polyethylene bags in the refrigerator at 2°C indicated that mushrooms can be stored only one week (Lasota and Furmańska-Szychowska, 1968). The aim of this work was to study the effect of storage of mushrooms in controlled atmospheres on their postharvest quality.

MATERIALS AND METHODS

Freshly harvested mushroom strain Somycel 11 were sorted by size and free from blemishes. Extremely small or large mushrooms were discarded and those selected had pilei about 30-35 mm in diameter. Sample size reached about 250 g. Each sample was weighed exactly and put into a pasteboard box of about 0.5 kg capacity. Samples of mushrooms were placed into 150 l plastic jars and stored in the dark at 2°C (± 0.2°C) with high humidity of about 90%. Mushrooms were stored under the following various controlled atmospheres:

N — normal atmosphere 0-0.5% CO_2 : 20.5% O_2,
I — 15% CO_2 : 1.5-2.0% O_2,
II — 10% CO_2 : 1.5-2.0% O_2,
III — continuous flow of nitrogen (20 l/h).

Samples were conditioned in the jars for 24 h at 2°C in a normal atmosphere and then the desired atmospheres were introduced. The levels of O_2 and CO_2 in the various treatments were monitored twice a day (morning and evening), using a O_2 gas analyzer (Pemolyt) and an infrared CO_2 analyzer (Infralyt). Corrections were made when needed.

Additional samples containing 7 uniform mushrooms were stored in each jar in order to study cap and stipe growth. Each mushroom was labelled and initial stipe length and diameter of the pileus were measured using vernier calipers. Stipe length was measured from the top of the cap to the stipe cut and pileus diameter was measured at the widest part of the cap. The samples were exposed to controlled atmospheres for 4, 8, 13, 21 and 28 days, at which time they were analyzed. Each time treatment combination had 3 replicates. The analyses covered: quality evaluation, fresh weight losses, dry matter content, objective color determination (whiteness values), toughness, carbohydrate contents, stipe length and pileus diameter of the labeled mushrooms from additional samples.

Toughness was determined using an Instron Food Testing Instrument model 1140 with a toothead plunger. Toughness is expressed as the force in newtons (N) necessary to puncture the cap of the mushroom.

Dry matter of the mushroom was determined by drying the samples at 70°C for 12 h and next at 100°C to constant weight.

The whiteness of mushrooms was determined using the Hunter Color and Color Difference Meter model D 25D2. The reflectance plate used for standarization of the instrument was a standard white plate for which Hunter values were: L = 91.9; a = —1.2; b = —0.3.

Glucose, fructose, trehalose and mannitol were determined by gas chromatography separation of their trimethylsilyl (TMS) ethers. Extrac-

tion of carbohydrates and TMS ether preparation were done according to Kline et al. (1970) with the some modifications (Horbowicz et al., 1980).

Confidence limit values were evaluated using the Dean and Dixon (1951) test.

RESULTS AND DISCUSSION

Quality of mushrooms during storage

Some characteristics in the quality spectrum of mushrooms were tested at the time of storage (Table 1). For 13 days, the acceptability (expressed in arbitrary degrees) for mushrooms stored in a normal atmosphere was good and next a comparatively sharp decline of this evaluation factor was observed. Acceptability of the mushrooms stored in a controlled atmosphere with different CO_2 and O_2 concentrations was stable and did not change during almost the entire period of storage, however, up to 13 days their acceptability was lower than that of the control (normal atmosphere).

For mushroom stored in normal atmosphere and in continuous flow of nitrogen, the percentage of mushrooms with yellow blotches increased gradually with the time of storage. Yellow blotches on mushrooms were probably caused by microbial contamination. According to these experiments and also from some literature data (Nichols and Hammond, 1973) it seems probable that high levels of CO_2 in the storage atmosphere suppressed the growth of aerobic microorganisms.

Controlled atmospheres also prevented processes related to cap opening. The percentage of mushrooms with torn velum or with open caps was higher for mushrooms stored in normal atmosphere than in other atmospheres.

Dry matter and fresh weight losses of mushrooms during storage

The period of storage in which insignificant changes of dry matter of mushrooms were observed was 8 days (Table 2). For the controlled atmosphere 10% CO_2 : 1.5-2% O_2, the dry matter of mushrooms did not change significantly during the entire period of storage.

The fresh weight losses of mushrooms during storage did not change as much as reported by Gormley (1975a), who held the mushrooms in chips in a refrigerator at 1°C; our results are rather similar to those

Table 1

Changes of some evaluation factors of mushrooms during storage under different conditions

Evaluation factors	Days of storage																			
	Storage conditions																			
	4				8				13				21				28			
	N	I	II	III	N	I	II	III	N	I	II	III	N	I	II	III	N	I	II	III
General look (acceptability in arbitrary degrees)*	4, 5	3, 5	3, 5	4	4	3, 5	3, 5	3, 5	4	3, 5	3, 5	3, 5	3	3, 5	3, 5	3	2	3, 5	3, 5	3
Percentage of mushrooms with yelow blotches	0	0	0	0	17.2	0	0	13.9	18.6	0	0	14.5	29.2	0	1.2	28.9	22.6	4.8	2.5	27.3
Percentage of mushrooms with torn velum																				
immediately after taking out	0	0	0	0	3.1	0	0	0	11.9	0	0	0	12.3	1.2	0	0	9.3	0	0	1.3
after 24 hrs storage in room temp. (+18°C)	20	0	0	0	30	0	0	0	30	0	0	0	0	0	0	0	10	0	0	0
Percentage of mushrooms with open caps																				
immediately after taking out	0	0	0	0	0	0	0	0	0	0	0	0	4.6	0	0	0	1.3	0	0	0
after 24 hrs storage in room temp. (+18°C)	10	0	0	0	20	0	0	0	20	0	0	0	0	0	0	0	10	0	0	0

N — normal atmosphere (+2°C); I — 15%CO_2:1.5-2%O_2; II — 10%CO_2:1.5-2%O_2; III — continuous flow of nitrogen.

* — 5 — very good; 4 — good; 3 — reasonable; 2 — poor; — 1 very poor.

Table 2

Dry matter content and fresh weight losses (expressed as a percentage of initial fresh weight) of mushrooms during storage under different conditions*

Days of storage	Normal atmosphere		15%CO_2:1.5-2%O_2		10%CO_2:1.5-2%O_2		Continuous flow of nitrogen	
	dry matter %	fresh weight losses %	dry matter %	fresh weight losses %	dry matter %	fresh weight losses %	dry matter %	fresh weight losses %
4	8.2±0.22	3.6±0.00	8.5±0.14	3.0±0.4	8.5±0.9	2.6±0.5	8.3±0.14	2.8±0.6
8	8.0±0.13	3.8±0.4	8.3±0.14	3.7±0.5	8.5±0.13	3.7±0.5	8.3±0.20	3.2±0.4
13	7.7±0.13	5.0±0.5	8.0±0.12	3.7±0.3	8.4±0.16	3.8±0.4	7.9±0.16	3.3±0.4
21	7.6±0.13	6.7±0.5	8.0±0.13	4.8±0.5	8.5±0.15	5.4±0.6	7.6±0.07	4.8±0.8
28	7.5±0.14	7.6±0.9	8.0±0.14	5.3±0.6	8.3±0.10	5.5±0.4	7.8±0.21	7.2±0.5

Dry matter of the initial mushrooms: 8.5±0.07

* Averages from 3 replicates ± confidence limits at $p = 0.95$.

Table 3

Whiteness values (Hunter L) changes of mushrooms during storage at different conditions*

Days of storage	Normal atmosphere		15%CO_2:1.5-2%O_2		10%CO_2:1.5-2%O_2		Continuous flow of nitrogen	
	whiteness* L	whiteness after 24 h at. +18°C	whiteness L	whiteness after 24 h at. +18°C	whiteness L	whiteness after 24 h at. +18°C	whiteness L	whiteness* after 24 h at. +18°C
4	86.1±0.8 (96.9)	80.8±1.6 (91.0)	75.6±1.8 (85.1)	71.9±1.8 (81.0)	72.3±1.0 (81.4)	69.5±2.2 (78.3)	80.9±1.8 (91.1)	75.1±2.5 (84.6)
8	85.1±1.6 (95.8)	78.3±1.4 (88.2)	72.7±1.8 (81.9)	69.0±1.8 (77.7)	69.6±2.5 (78.4)	66.2±1.5 (74.5)	75.8±1.5 (85.4)	72.5±2.4 (81.6)
13	80.4±2.7 (90.5)	74.6±2.2 (84.0)	71.9±2.0 (81.0)	66.5±2.2 (74.9)	71.2±2.5 (80.2)	66.8±1.9 (75.2)	76.5±2.1 (86.1)	70.9±2.6 (79.8)
21	78.3±2.3 (88.2)	73.7±1.6 (83.0)	68.8±3.2 (77.5)	67.2±3.2 (75.7)	68.0±2.3 (76.6)	64.5±1.8 (72.6)	69.3±2.7 (78.0)	66.0±3.1 (74.3)
28	71.8±2.1 (80.9)	66.4±2.3 (74.8)	67.5±2.6 (76.0)	64.5±2.7 (72.6)	66.1±3.1 (74.4)	62.0±1.9 (69.8)	66.6±2.5 (75.0)	61.7±2.5 (69.5)

Initial mushrooms: L = 88.8±1.1

* Averages from 10 mushrooms ± confidence limits at $p = 0.95$.

Percentage of initial whiteness in parentheses.

reported by Nichols and Hammond (1983), where the mushrooms were stored in pre-packs overwrapped with plastic films.

Generally it can be observed (Table 2) that fresh weight losses of mushrooms stored in normal atmosphere gradually and significantly increased after 8 days as compared with shorter storage times or to other treatments. As can be seen from Table 2, fresh weight losses of mushrooms for all treatments were relatively high during the first 4 days of storage and next for controlled atmospheres that did not change significantly up to 13 days of storage.

Whiteness of mushrooms during storage

Whiteness is a very important quality factor for *Agaricus bisporus*. The results for whiteness are presented in Table 3. These indicate that the whiteness value L depends on storage time and conditions. According to Gormley (1975b), the lowest acceptability whiteness values L are 69 for consumers and 80 for wholesale. Results of whiteness and loss of whiteness during storage indicated that normal atmosphere appeared better for keeping whiteness of mushrooms than other atmospheres. As can be seen from Table 3, samples from the normal atmosphere were acceptable to the consumer from a whiteness point of view up to 28 days of storage or 21 days with a subsequent storage of samples at +18°C for 24 h.

Mushrooms exposed to a continuous flow of nitrogen were browner than those from the normal atmosphere but were still acceptable to the consumer up to 21 days of storage or 13 days with a subsequent storage of samples at + 18°C for 24 h. Controlled atmospheres were associated with increased browning of mushrooms to a much higher degree in com-

Table

Influence of storage time and storage conditions on carbohydrate

Days of storage	Fructose (mg/100 g)				Glucose (mg/100 g)				
	N	I	II	III	N	I	II	III	N
4	tr.	tr.	tr.	tr.	10.2±1.0	9.1±1.8	6.3±2.0	6.3±1.6	92.7±9.7
8	tr.	tr.	tr.	tr.	8.8±1.9	9.3±2.6	6.2±2.0	11.1±1.9	55.5±12.1
13	tr.	tr.	tr.	tr.	11.3±2.5	13.1±2.5	8.4±1.3	6.6±1.3	95.3±14.0
21	tr.	tr.	tr.	tr.	4.5±1.0	5.3±1.1	4.5±1.0	5.3±1.1	114.9±11.8
28	tr.	tr.	tr.	tr.	tr.	tr.	tr.	tr.	95.0±8.6
Initial mushrooms		7.8±1.6					8.6±1.9		

* Averages from 3 replicates ± confidence limits at p = 0.95.
tr. — traces (below 3 mg/100 g).

parison with the normal atmosphere or continuous flow of nitrogen. The results confirm data presented by N i c h o l s and H a m m o n d (1973), that a high CO_2 concentration in the storage atmosphere decreased whiteness of mushrooms at 2°C. Although whiteness is one the of most important quality factors, it seems to us that other characteristics play a very important role in consumer choice. General characteristics were termed "general appearance". Comparing results of whiteness values (Table 3) with those of "general appearance" presented in Table 1 for a time longer than 13 days of storage a divergence can be observed. People from the laboratory staff who tested mushroom samples prefered those, in spite of a whiteness value lower than that of others.

Carbohydrate changes during storage

Soluble carbohydrates such as fructose, glucose, trehalose and mannitol were determined (Table 4). Glucose was present as a minor constituent and no fructose was found after 4 days of storage. Mannitol is a major soluble carbohydrate in mushrooms while trehalose is present at lower levels. Trehalose in mushrooms decreased during first 4 days of storage in all controlled atmospheres and then it reached the level as for initial mushrooms. The change in mannitol during the storage of mushrooms was less pronounced although a general trend towards its decrease (not always statistically significant) was seen.

Stipe elongation and cap expansion of mushrooms during storage

Storage atmospheres markedly affected the growth of mushrooms (Figs. 1, 2). All controlled atmospheres significantly inhibited cap expan-

4
content in mushrooms (expressed on a fresh weight base)*

Trehalose (mg/100 g)				Mannitol (g/100 g)		
I	II	III	N	I	II	III
63.7±6.5	63.1±9.7	60.0±10.1	2.01±0.16	2.07±0.11	2.06±0.13	2.08±0.16
89.7±12.1	88.7±10.4	91.2±11.0	2.07±0.17	1.92±0,15	1.69±0.11	1.92±0.11
86.6±12.4	88.7±14.1	89.4±9.3	2.01±0.13	1.85±0.10	1.87±0.19	1.97±0.13
79.3±9.0	75.1±9.0	79.4±9.4	1.91±0.28	1.57±0.17	1.70±0.12	1.54±0.11
56.7±7.9	63.0±10.8	72.0±7.8	1.73±0.10	1.57±0.12	1.78±0.12	1.66±0.15
	86.7±7.7				2.12±0.19	

Description for N, I, II and III see Table 1.

sion as compared with the normal atmosphere (Fig. 1). The cap diameter gradually increased up to the 13th day during storage of mushrooms in normal atmosphere. Also slight, but statistically significant growth of the pileus was observed up to the 13th day of storage under continuous flow of nitrogen. The response of mushrooms to 10% CO_2 : 1.5-2% O_2 atmosphere appears to have a dual nature: cap growth inhibition, and no action on stipe elongation in comparison with normal

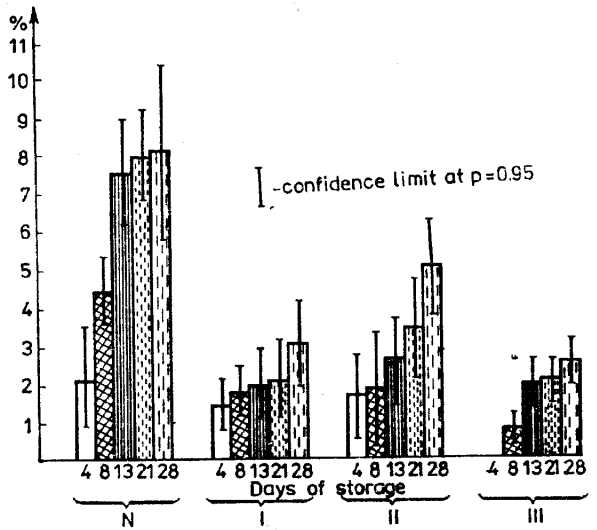

Fig. 1. Expansion of cap diameter (expressed as a percentage of the initial cap diameter) of mushrooms during storage under different conditions. N — control, normal atmosphere (+2°C), I — 15% CO_2 : 1.5-2% O_2 (+2°C), II — 10% CO_2 : 1.5-2% (O_2 (+2°), III — continuous flow of nitrogen (+2°C)

atmosphere. Storage of mushrooms in an atmosphere of 15% CO_2 : 1.5-2% O_2 and in a continuous flow of nitrogen significantly inhibited stipe elongation during the entire time of storage as compared with the control (Fig. 2). During storage of mushrooms in normal atmosphere, stipe elongation gradually increased up to 13 days at the same rate as cap expansion (Figs. 1, 2). As can be seen on Fig. 2 concentration of 10% CO_2 and 1.5-2% O_2 markedly stimulated stipe elongation during 4 days of mushroom storage as compared with normal atmosphere. Our results are strikingly parallel to those reported by Murr and Morris (1975) in which 0% O_2 or high CO_2 concentrations inhibited growth of mushrooms. We also found that 10% CO_2 similary as 5% CO_2 (Murr and Morris, 1975) stimulated elongation of stipes as compared to the control.

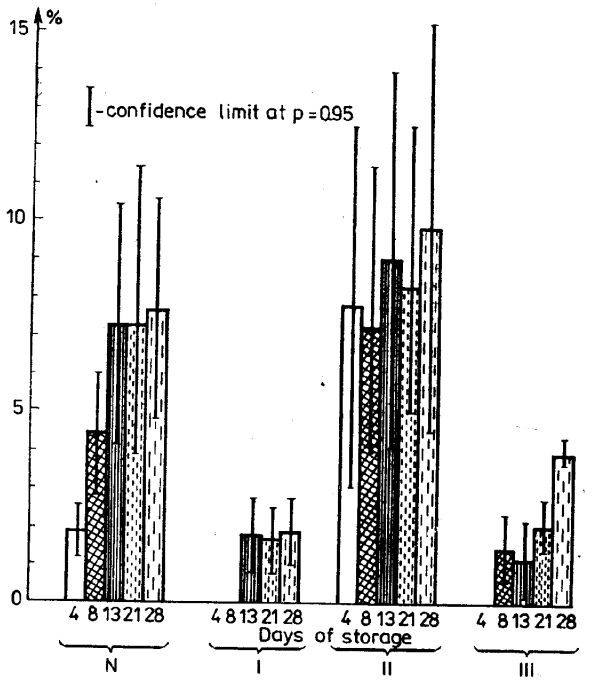

Fig. 2. Elongation of the stipe of mushrooms (expressed as a percentage of the initial stipe length) during storage under different conditions. N — control, normal atmosphere (+2°C), I — 15% CO_2 : 1.5-2% O_2 (+2°C), II — 10% CO_2 : 1.5-2% O_2 (+2°C), III — continuous flow of nitrogen (+2°C)

Biochemical and texture changes of mushrooms during storage

Storage atmospheres had marked effects on the toughness of mushrooms (Table 5). Toughness of mushrooms stored in normal atmosphere markedly decreased and after 8 days their toughness was significantly lower than that of the initial mushrooms. Toughness of mushrooms stored in 15% CO_2 and 1.5-2% O_2 was higher than that of initial mushrooms and those stored in the normal atmosphere. Continuous flow of nitrogen and 10% CO_2 : 1.5-2% O_2 (except 4 days of storage) did not influence toughness as compared to the initial mushrooms.

The post-harvest development of the mushroom must involve a considerable mobilization of reserves. It has already been shown (Hammond and Nichols, 1975) that mannitol and trehalose are probably post-harvest respiratory substrates. According to Hammond (1979), a non-structural polysaccharide was the major component too, which was metabolized during storage. The evidence from partial hydrolysis experiments suggests that the polysaccharide is composed of glucose

Table 5

Effect of storage under different conditions on toughness of mushrooms (expressed as force to puncture)*

Days of storage	Normal atmosphere	15% CO_2:1.5-2% O_2	10% CO_2:1.5-2% O_2	Continuous flow of nitrogen
4	16.4±2.3	18.4±1.0	19.8±1.3	16.2±1.0
8	13.8±1.0	17.2±2.8	17.8±2.6	16.9±1.5
13	10.0±1.5	18.3±1.8	16.4±2.0	17.1±2.3
21	7.3±1.1	19.2±2.0	15.7±2.0	17.3±2.0
28	6.7±1.0	16.3±1.8	14.2±2.3	16.7±2.5

Initial mushrooms: 14.7±0.8 (N)

* Averages from 7 mushroom ± confidence limits at p = 0.95.
Force to puncture was measured using a toothead plunger.

residues joined by $\alpha \leftarrow 1.4$ and $\alpha - 1.6$ linkages and was tentatively identified as glycogen. Changes in cell wall material during storage (Hammond, 1978) suggest breakdown and transfer of some material to or from the cytoplasm. Considerable breakdown of nitrogenous materials must occur to account for the increase in urea content after harvest. Murr and Morris (1975) observed increased protease activity during storage which probably mediates increased protein turnover. The fall in free amino acids (Murr and Morris, 1975; Maggioni et al., 1968) during storage could account for the urea synthesis. Mushrooms assimilate almost all low molecular weight compounds containing C and N from the substrate on which they are growing. After harvest and during storage the C and N supply is cut, so the mushrooms must involve considerable utilization of reserves and materials due to physiological functions under new circumstances. As mentioned above, considerable changes in composition occur during the post-harvest life of the mushrooms. Cold storage, and the use of suitable gas atmospheres, are more or less effective in retarding these changes.

CONCLUSIONS

1. Acceptability of mushrooms stored in controlled atmospheres 10-15% CO_2 : 1.5-2% O_2 was stable and did not change during 21 days of storage. Acceptability of mushrooms from controlled atmospheres was lower during 14 days of storage in comparison with control (normal) atmosphere and continuous flow of nitrogen.

2. Controlled atmospheres suppressed the growth of some microorganisms and prevented processes related to cap opening.

3. Controlled atmospheres at different CO_2 and O_2 concentrations

10-15% CO_2 and 0.5-1.5% O_2) were associated with an increased browning of mushrooms to a much higher degree as compared with normal atmosphere or continuous flow of nitrogen. Normal atmosphere appeared better for keeping whiteness of mushrooms than other treatments.

4. Continuous flow of nitrogen and 15% CO_2 : 1.5-2% O_2 inhibited cap growth and stipe elongation, while 10% CO_2 : 1.5-2% O_2 appears to involve a dual effect: cap growth inhibition and no action on stipe elongation as compared with normal atmosphere.

5. Toughness of mushrooms during storage in controlled atmospheres and in a continuous flow of nitrogen did not differ considerably from the initial mushrooms, while this for mushrooms from normal atmosphere decreased gradually.

6. Mushrooms are perishable material and according to the obtained results could be stored in normal atmosphere and temperature + 2°C up to 4 days without visible changes of general appearance and this can be recommended for practice.

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Wpływ warunków składowania na jakość grzybów uprawnych (*Agaricus bisporus* (Lange) Sing.)

Streszczenie

Przebadano niektóre wskaźniki jakości pieczarek składowanych w następujących kontrolowanych atmosferach w temperaturze 2°C: Normalna (kontrola) 0 — 0,5% CO_2 : 20,5% O_2; I — 15% CO_2 : 1,5-2,0% O_2, II — 10% CO_2 : 1,5-2,0% O_2; III — ciągły przepływ azotu (20 $l \cdot godz.^{-1}$).

Stężenie 15% CO_2 : 1,5-2,0 O_2 oraz ciągły przepływ azotu hamowały wzrost kapeluszy i wydłużanie się trzonków grzybów, natomiast stężenie 10% CO_2 : 1,5-2,0% O_2 wpływało hamująco tylko na wzrost kapeluszy. Kontrolowane atmosfery hamowały również wzrost niektórych mikroorganizmów. Twardość grzybów składowanych w normalnej atmosferze obniżała się w miarę czasu składowania, natomiast atmosfery składające się z 10% CO_2 : 1,5-2,0% O_2 oraz ciągły przepływ azotu utrzymywały twardość pieczarek na poziomie twardości grzybów świeżo zebranych. Oceny akceptacji pieczarek składowanych w kontrolowanych atmosferach w okresie 13 dni były niższe w porównaniu do ocen grzybów składowanych w normalnej atmosferze. Kontrolowane atmosfery obniżały również wskaźnik białej barwy grzybów w większym stopniu niż normalna atmosfera.