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POSTHARVEST QUALITY CHANGES OF MUSHROOMS (*Agaricus bisporus*): COMPARISON OF INTACT AND SLICED MUSHROOMS

MANTARLARDA (*Agaricus bisporus*) HASAT SONRASI KALİTE DEĞİŞİMLERİ: BÜTÜN VE DİLİMLENMİŞ MANTARLARIN KARŞILAŞTIRILMASI

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ÖZET: Araştırma, 0°, 5° ve 10°C'lerde 2 hafta muhafaza edilen bütün ve dilimlenmiş mantarlarda muhafaza süresince oluşan kalite değişimlerini ve raf ömrünü karşılaştırmak amacı ile gerçekleştirilmiştir.

Pazarlama sırasında ortaya çıkabilen 10°C sıcaklıklar gerek bütün gerek dilimlenmiş olarak pazarlanacak mantarların raf ömrünü kısaltmaktadır. Renk ve sertlik değişimi ile şapka açılması olarak belirlenen kalite değişimleri yüksek sıcaklıklarda hızlanmaktadır. Denemede dilimlenmiş mantarların; solunum şiddeti, kararma ve yumuşama dikkate alındığında bütün mantarlara oranla daha duyarlı oldukları saptanmıştır. Bu nedenle özellikle dilimlenmiş mantarların 5° ve 10°C yerine 0°C'de muhafaza edilmesi gerekmektedir. Buna karşın bütün olarak pazarlanacak mantarlarda sıcaklık dereceleri arasındaki kalite farkı oldukça düşük düzeylerde kalmıştır.

SUMMARY: The aim of present research was to compare the shelf-life and quality changes of intact and sliced mushrooms held at 0°, 5°, and 10°C for up to two weeks.

Storage of intact and sliced mushrooms at 10°C is unacceptable to maintain shelf-life, but represents conditions which may occur during marketing. Deterioration of the mushrooms, as measured by color changes, firmness and cap opening were rapid at higher temperatures. Sliced mushrooms were substantially more perishable than intact mushrooms, these differences being reflected in higher respiration rates, more rapid browning of the surface and more rapid decreases in firmness over the storage period. There were definite advantages to storing the sliced mushrooms at 0°C rather than 5°C to maintain shelf-life and quality, whereas for the intact mushrooms, quality differences were small between these storage temperatures.

INTRODUCTION

The common cultivated mushroom loses its quality rapidly during postharvest handling (MURR and MORRIS 1975, BELMAN 1988). After harvest mushrooms continue their course of development leading to maturation and senescence of the sporophore (GOODENOUGH et al. 1977, HAMMOND 1979). Important quality changes include discoloration, stem elongation, cap opening and loss of firmness (McCANNA and GORMLEY 1968). These quality changes may be greater during the handling of sliced mushrooms and therefore make temperature management even more critical.

The objective of the present research was to compare the shelf-life and quality changes of intact and sliced mushrooms held at 0°, 5°, and 10°C for up to two weeks.

MATERIALS AND METHODS

For this experiment, mushroom sporophores (A. bisporus) were obtained from Petaluma Mushroom Farm in USA. Mushrooms at the "button" stage were matched according to cap characteristics, using those of a 30-35 mm diameter with the velum differentiated but unbroken. Sliced mushrooms were prepared from intact mushrooms cooled and sliced at 0°C on a commercial tomato slicer (slices 3/8 inch) which had been previously cleaned with ethanol.

Samples weighing approximately 200 g for intact mushrooms and 100 g for sliced mushrooms were placed in glass jars and connected to a flow-board through which a humidified (90-95 %RH) air stream passed. Flow rates were sufficient to maintain CO_2 below 0.5 % and permit its measurement by analysis of 1 ml gaseous samples on an Infra-Red Gas Analyzer. At intervals of 3 days, the mushrooms were assessed for quality changes, and samples were also evaluated after transfer to 15°C for 24 hours to simulate market handling.

Quality was assessed as changes in color, firmness and cap opening. The whiteness of the intact mushrooms was measured objectively as L value by a Minolta Color Meter. Color of the cap for the intact

and of the pileous for the sliced mushrooms was also estimated by a hedonic scale of 9 to 1, where: 9: initial whiteness, 7: creamy-white, 5: light brown and limit of commercial acceptability 3: brown and 1: dark brown.

Firmness was determined in two ways: measurement of the deformation in mm when the mushroom was held under a 500 g weight for 15 seconds and by measurement of the force (in kg) needed to shear the mushroom cap by a knife-like probe 6 mm long with a 1 mm wide blade after removal of the cap skin. Shear force and color of the sliced mushrooms were measured at the midpoint of the sliced cap area.

Changes in the developmental stage were determined as "cap opening" using a hedonic scale of 0 to 6, where; 0: veil attached to stipe, 1: veil starting to separete, 2: half of the veil separated, 3: veil almost completely separated, 4: veil completely separated, 5: cap completely open and gills visible, and 6: cap is flat in shape.

All results are based on observations from 3 replications, each consisting of 10 mushrooms or slices. Respiration rate of mushrooms which were placed in glass jars and connected to a flow-board system were measured with an Infra-Red Gas Analyzer.

RESULTS

Respiration rates of intact and sliced mushrooms

Figure 1 summarize the respiratory patterns of the intact and sliced mushrooms over a two week period at 0°C. According to statistical assay (ANOVA) there were significant differences in respiration rate between mushrooms stored at 0°, 5°, and 10°C. Some significant effect was also obtained for the sliced mushrooms. In this experiment Q_{10} value was calculated as 6.27.

Respiration rates for intact mushrooms after 3 days at 10°C were about 2.5 and 5 times those at 5° and 0°C, respectively. For the intact mushrooms, respiration tended to increase with time at 0°C, remained almost constant at 5°C and showed a rapid increase followed by a decline at 10°C. In all cases, sliced mushrooms had noticeably higher respiration rates than intact mushrooms. The respiratory patterns for the sliced mushrooms at 0° and 10°C was similar to those of the respective intact mushrooms. At 5°C however respiration of the sliced mushrooms tended to increase with time.

Color changes:

Table 1 shows hedonic color changes of the mushrooms at 3 days intervals and after the additional 1 day transfer period. Color of the intact mushrooms deteriorated rapidly at 10°C. The whiteness of the cap before and after transfer was slightly better when held at 0°C. The whiteness of the 12 and 15 day observations, color was lightly better for the 5°C samples. For the sliced mushrooms, color of the pileus was maintained best when they were held at 0°C. In this case, the differences in brown color development between 0° and 5°C was dramatic. In all cases, color quality depended on the temperature of storage and transfer to 15°C for 1 day resulted in a further reduction of that quality.

The L values for stored intact and sliced mushrooms are shown in Table 2 and 3.

L value of stored intact mushrooms was as 90.44 at the beginning of storage period. This value decreased to 77.25 after 2 weeks of storage and same mushrooms showed a value of 75.54 after transfer to 15°C for 24 hours. For the mushrooms stored at 5°C, L value was 79.82 at the end of 2 weeks of storage and it was found as 76.36 after transfer to 15°C. Statistical assay showed a significant differences of L values in between temperature.

The color deterioration were more rapid in the sliced mushrooms, and final L values were substantially lower than for corresponding intact mushrooms, although initial values were the same. L values also decreased more after transfer. L values was measured as 74.69 and 69.25 at the end of 2 weeks storage at 0°C and after transfer to 15°C respectively. These values were 65.01 and 58.01 at 5°C. L value of sliced mushrooms stored at 10°C decreased to 76.14 within one week and to 64.86 which indicates the lose of market value after transfer to 15°C for 24 hours.

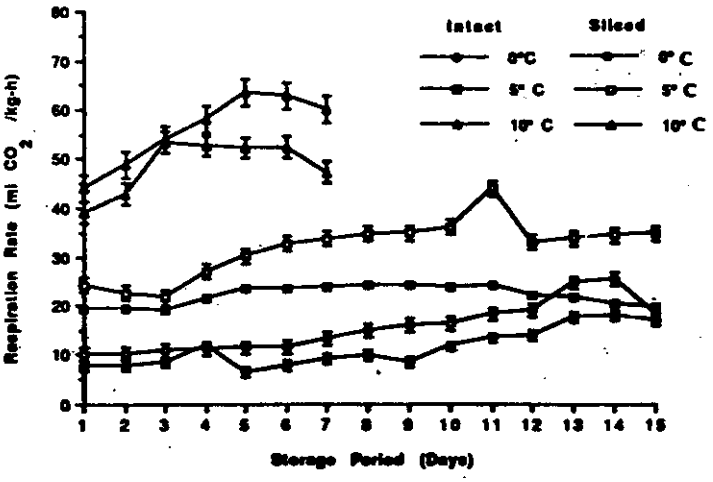

Figure 1. Respiration rates of intact and sliced mushrooms stored at 0°, 5°, and 10°C.

Firmness changes

Changes in deformation and shear force are shown in Table 4. Deformation values for the intact mushrooms increased most at 10°C and showed a further large increase after transfer to 15°C for 24 hours. There were a significant differences between 10°C and the others but not significant differences between 0° and 5°C until the 6th day of storage. After 6th day, significant differences obtained between these temperatures. Similar trends with time and temperature were also observed with shear force measurements. For the intact mushrooms, there were significant differences between temperatures during storage period, but for the sliced mushrooms significant differences were obtained at the first week of storage between 10°C and the others. After 6th day, the differences were significant between 0° and 5°C.

Table 1. Hedonic color changes of the cap of intact and sliced mushrooms stored at 0°, 5°, and 10°C

Intact Mushrooms				After transfer to 15°C for 24 h			Sliced Mushrooms				to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C	Days	0°C	5°C	10°C	0°c	5°C	10°C
0	9	9	9	9	9	9	0	9	9	9	9	9	9
3	8	9	7	7	8	6	3	9	8	6	8	6	6
6	8	8	6	7	7	5	6	8	7	5	8	4	4
9	8	7	-	6	7	-	9	7	3	-	7	1	-
12	6	6	-	5	6	-	12	7	1	-	6	1	-
15	5	6	-	5	6	-	15	7	1	-	6	1	-

Cap Opening

Developmental changes occuring in the intact mushrooms can be etsimated by observing the opening of the cap. From Table 5, it is readily apparent that cap opening occurred most rapidly at 10°C and it was significantly different than 0° and 5°C. After transfer to 15°C, opening scores increased in different rates due to the temperatures from which mushrooms were transferred.

Table 2. Changes in L value of intact mushrooms

	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C
0	90.44 a	90.44 a	90.44 a	90.44 a	90.44 a	90.44 a
3	84.64 a	85.58 b	82.60 c	83.77 a	83.93 a	78.95 d
6	82.78 a	81.10 b	78.91 c	82.13 a	79.53 cd	75.31 e
9	81.52 a	79.15 b	-	78.45 b	78.85 b	-
12	77.54 a	76.82 a	-	78.83 b	76.93 a	-
15	77.25 a	79.82 b	-	75.54 c	76.36 ac	-

Table 3. Changes in L value of sliced mushrooms

	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C
0	90.44 a	90.44 a	90.44 a	90.44 a	90.44 a	90.44 a
3	82.93 a	82.25 a	79.25 b	80.59 b	80.36 b	70.49 c
6	79.45 a	77.53 b	76.14 c	78.91 a	76.87 bc	64.86 e
9	78.19 a	65.36 b	-	74.87 c	59.21 d	-
12	77.88 a	65.27 b	-	76.02 c	59.12 d	-
15	74.69 a	65.01 b	-	69.25 c	58.05 de	-

Table 4. Changes in shear force and deformation of mushrooms

Shear Force (kg) INTACT						
	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C
0	1.27 a	1.27 a	1.27 a	1.27 a	1.27 a	1.27 a
3	1.19 a	0.99 b	0.80 cd	0.98 b	0.90 bc	0.71 d
6	1.13 a	0.99 b	0.65 c	0.95 b	0.90 b	0.39 d
9	1.00 a	0.93 b	-	0.87 c	0.89 bc	-
12	0.97 a	0.87 b	-	0.71 c	0.83 d	-
15	0.81 a	0.80 a	-	0.79 a	0.56 b	-
Shear Force (kg) SLICED						
	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°
0	1.07 a	1.07 a	1.07 a	1.07 a	1.07 a	1.07 a
3	1.04 a	0.98 ab	0.94 ab	0.91 b	0.90 b	0.64 c
6	0.95 a	0.85 ac	0.52 bd	0.80 c	0.81 c	0.45 d
9	0.91 a	0.55 b	-	0.77 c	0.45 d	-
12	0.90 a	0.56 b	-	0.64 c	0.44 d	-
15	0.68 a	0.43 b	-	0.37 b	0.36 b	-
Deformation (mm) INTACT						
	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C
0	1.03 a	1.03 a	1.03 a	1.03 a	1.03 a	1.03 a
3	1.35 a	1.33 ad	1.74 b	1.60 c	1.34 ad	1.68 e
6	1.55 a	1.64 ad	1.43 b	1.93 c	1.83 cd	3.39 e
9	1.56 a	1.74 b	-	1.95 c	1.95 c	-
12	1.69 a	1.89 b	-	2.19 c	2.21 c	-
15	2.16 a	1.92 b	-	2.43 c	1.23 a	-

DISCUSSION

Storage of intact and sliced mushrooms at 10°C is unacceptable to maintain shelf-life, but represents conditions which may occur during marketing. Deterioration of the mushrooms, as measured by color changes, firmness changes and cap opening were rapid at higher temperatures (NICHOLS 1988, TUNCEL and AĞAOĞLU 1992). As expected, sliced mushrooms were substantially more perishable than intact mushrooms, these differences being reflected in higher respiration rates, more rapid browning of the surface and more rapid decreases in firmness over the storage period. There were definite advantages to storing the sliced mushrooms at 0°C rather than 5°C to maintain self-life and quality, whereas for the intact mushrooms, quality differences were small between these storage temperatures.

Table 5. Changes in the cap opening score of intact mushrooms stored at 0°, 5°, and 10°C.

	Cold Storage			After transfer to 15°C for 24 h		
Days	0°C	5°C	10°C	0°C	5°C	10°C
0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.1	0.7	0.2	0.3	2.7
6	0.0	0.1	1.8	0.2	0.4	4.2
9	0.2	0.2	-	0.2	0.5	-
12	0.2	0.5	-	0.2	0.8	-
15	0.3	0.5	-	0.3	1.6	-

Mushroom is classified among the products having high respiration rate (NICHOLS 1985). Respiration rate depends on the stage of maturity and environmental conditions (CHO et al. 1982, AĞAOĞLU and TUNCEL 1992). HOU and WU (1972) indicated that respiration rate increases as related to maturity. In this experiment, respiration rate showed an increase and following decreases during storage as MURR and MORRIS (1975) indicated previously. It is thought that the reason of increased respiration rate is due to the growth in gill tissues. On the other hand the reason for declined respiration rate is to use the carbohydrates as storage substances.

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