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PREPACKAGING AND SHELF LIFE OF MUSHROOMS

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ABSTRACT

Mushrooms covered with the PVC film Resinite in a Hartmann Foodtainer dish had a shelf life of 5 to 7 days when stored at 15° to 21°C. Uncovered mushrooms had a shelf life of 2 to 4 days under similar conditions. Treatment of mushrooms with solutions of antioxidants followed by prepackaging with Resinite gave a shelf life of only 3 to 5 days.

The shear press and reflectometer were found suitable for measuring texture and whiteness of mushrooms.

Toughness of covered and uncovered mushrooms increased over a 5-day period. Uncovered mushrooms lost 31.6 percent of their original whiteness after 4 days while covered mushrooms lost 18.8 percent. The corresponding moisture losses were 68.3 and 10.8 percent.

INTRODUCTION

Market research in Britain on the sale of Irish mushrooms by Harkin (1) and MacCanna (2) indicated that both colour retention and general presentation could be improved. English growers have test marketed prepacked mushrooms on the British markets (3), but consumer response was poor. This may have been due to a combination of factors, including the lack of consumer education in prepacked produce, and the use of an unsuitable film for the prepack which resulted in excessive moisture loss, discolouration and rotting. If these disadvantages could be eliminated mushroom growers could benefit from prepackaging in many ways, *viz.* (a) longer shelf life, (b) direct sales to supermarkets, (c) possibility of a premium for mushrooms sold in prepacks, (d) greater adaptability to brand advertising.

Extensive work has been done in the U.S.A. on the shelf life of mushrooms and on factors which cause mushrooms to lose their attractive appearance. Browning caused by the enzyme polyphenol oxidase (4) is one of the major deleterious factors. Polyphenol oxidase is found in mushroom hyphal strands which lie on the surface of the cap. Handling and bumping of mushrooms cause the hyphal strands to break which releases the enzyme. Glandorf (5) increased the shelf life of mushrooms by dipping them in potacki (a mixture of salts of organic acids) for 15 minutes. Hughes (6, 7) and Woodmansee (8) have used antioxidants successfully to prevent browning in mushrooms. However, antioxidant treatments require controlled conditions and their application at grower level is difficult.

Preliminary studies at Kinsealy have shown that water loss from mushrooms is possibly a greater deleterious factor than browning caused by polyphenol oxidase. Since prepackaging mushrooms with some synthetic films greatly reduces water loss, effects of prepackaging, antioxidants and a combination of prepackaging/antioxidants on the shelf life of mushrooms were studied.

EXPERIMENTAL

In this paper the term covered mushrooms refers to 8 to 12 cultivated mushrooms (*Agaricus bisporus*) in a Hartmann Foodtainer dish $5\frac{1}{2}$ x $5\frac{1}{2}$ x $\frac{3}{4}$ in. wrapped with a synthetic film. The term uncovered mushrooms refers to 8 to 12 mushrooms in a similar unwrapped container.

Shelf life of mushrooms is defined as the length of time they remain in a saleable condition.

A series of experiments comparing covered and uncovered mushrooms was carried out. In all cases mushrooms were stored at 15° to 21°C.

Choice of film for prepackaging

Eight synthetic films (numbered 1 to 8) were used in the prepackaging experiment. Five containers of mushrooms were covered with each film, giving a total of 40 packs. Each container was weighed when covered and again after 24 and 48 hours. All packs had the same initial weight. Water loss was measured from mushrooms prepacked with different films. In addition, condensation on the underside of the film and mushroom appearance within the pack were noted. Resinite (film no. 4) was chosen for all further experiments.

Texture and water loss

Mushrooms, with stipes trimmed, were weighed individually at the beginning of the experiment (day 1) and placed in 20 containers, 10 of which were covered. On successive days each individual mushroom from two covered and two uncovered containers was reweighed and texture measurements taken on an Allo Kramer shear press using a standard test cell. A shear press simulates the chewing action of teeth and gives an accurate measurement of texture (9, 10). The experiment continued over 5 days and was repeated twice.

A similar experiment was undertaken using covered and uncovered pairs of mushrooms (two mushrooms of the same weight and approximately the same shape) to obtain a more precise picture of the relationship between water loss and texture. Paired mushrooms were compared on days 1, 2; 1, 3; 1, 4; and 1, 5 of the experiment. On the first day both mushrooms were weighed and one was shear pressed. Twenty-four hours later the second mushroom was reweighed and shear pressed. Similarly other mushrooms were reweighed and shear pressed after 48 (day 3), 72 (day 4) and 96 hours (day 5).

Preliminary studies showed that the position of the mushroom in the shear press cell affected the texture reading. The shear press values for paired mushrooms varied, depending on whether the gills were facing upwards or downwards in the cell. It was also important to use mushrooms of similar types for shear pressing experiments, *e.g.*, a button had a higher reading than a flat.

Colour determination and water loss

Thirty-two containers each of covered and uncovered mushrooms were prepared on day 1 of the experiment. The whiteness of each mushroom cap was measured using an EEL reflectometer. The reflectometer cell was placed on 5 parts of the cap and the mean reading noted. In a preliminary experiment mushroom whiteness was measured at the brightest spot on the cap, but this was not successful as even badly discoloured mushrooms usually contained at least one white patch. The reflectometer cell was calibrated using a standard block of magnesium carbonate which gave a dial reading of 100 on the galvanometer. The weight and average whiteness of mushrooms in each container were measured. On days 2, 3, 4 and 5 eight containers of covered and eight of uncovered mushrooms were reweighed and the average whiteness measured.

Antioxidant applications

Batches of freshly picked mushrooms were treated with one of the following antioxidant solutions (conc. 1,000 ppm, in distilled water): (a) sodium bicarbonate/sodium dithionite 1:1; (b) ascorbic acid/sodium sulphite 1:1; (c) sodium sulphite/sodium chloride 1:1; and (d) sodium dithionite/sodium chloride 1:1.

The solutions were applied by two methods:

i) Freshly picked mushrooms that had received the minimum of handling were immersed in a beaker of antioxidant solution (10°C) for 2 minutes. Agitation during the immersion caused mushrooms to rub against each other and against the walls of the beaker which removed particles of casing soil and hyphal strands. The mushrooms were dried by capillarity on filter paper (Whatman no. 1, 32 cm) for 1 hour[1] and placed in a punnet which was shaken gently for 2 minutes to simulate travelling. The treated

[1] A preliminary test comparing drying times of ¼, ½, ¾ and 1 hour for mushrooms washed in water showed that those dried for 1 hour had the longest shelf life

mushrooms were divided into two batches, one of which was covered. Six containers of mushrooms were used for each antioxidant treatment and the experiment was repeated twice. Individual packs were graded daily by comparing them with freshly picked mushrooms. Sliminess, colour deterioration, condensation on the film and general appearance were noted.

ii) Freshly picked mushrooms that had received the minimum of handling were placed in four boxes (stipes facing downwards). Each box was sprayed with one of the above antioxidant solutions using a chromatography sprayer. The mushrooms were dried, packed and graded according to appearance.

RESULTS

Choice of film for prepackaging

Water loss from mushrooms covered with Resinite (film no. 4: a stabilised and plasticised PVC film) and with films numbered 3, 6 and 8 was less than from those covered with other films (Table I).

White colour retention and good appearance were maintained for 5 to 7 days when containers of mushrooms, covered with Resinite, were stored at 15° to 21°C. Condensation took place on the underside of films numbered 3, 6 and 8 making the appearance of the packs unattractive. Excessive water loss through perforated films (nos. 1, 2, 5 and 7) caused wrinkling of mushrooms and brown patches were visible on the caps opposite each perforation.

TABLE I: Weight loss from mushrooms covered with different films

	Combined weight loss (g) of 5 packs		
Film	24 hours after packing	48 hours after packing	Mean[1]
1	33.5	49.7	41.6 a
2	23.7	38.5	31.1 b
3	13.3	16.3	14.8 c
4	11.0	13.3	12.1 c
5	24.2	36.4	30.3 b
6	14.3	18.9	16.6 c
7	23.1	30.1	26.6 b
8	14.8	19.2	17.0 c
Mean	19.8	27.8	
	F test	SE[2]	
Film (F)	***	±3.33	
Time (T)	**	±1.67	
Interaction (F x T)	NS	±4.71	

[1] Means followed by a common letter are not significantly different (Duncan's multiple range test: $p < 0.05$)

[2] Standard error of treatment mean (df = 60)

TABLE II: Relationship between initial weight[1] and shear press reading in covered (Resinite) and uncovered mushrooms (See Figs. 1 and 2)

	Shear press dial reading[2] (mean)	Weight of mushroom in g[1] (mean)	Constant	Regression coef	Standard error of (b)	Corr. coef	Degrees of freedom
	y	*x*	*a*	*b*	SE (*b*)	*r*	df
Freshly picked	0.099	12.592	0.0039	0.0076	±0.0006	0.875	48
Covered 24 hours	0.154	15.463	—0.0043	0.0102	±0.0004	0.956	49
48 hours	0.156	15.755	—0.0025	0.0101	±0.0006	0.936	45
72 hours	0.175	15.535	—0.0044	0.0116	±0.0008	0.914	44
96 hours	0.176	14.211	—0.0091	0.0130	±0.0006	0.956	51
Uncovered							
24 hours	0.125	13.659	—0.0197	0.0106	±0.0004	0.966	52
48 hours	0.122	13.313	—0.0132	0.0101	±0.0004	0.961	50
72 hours	0.119	13.420	—0.0114	0.0098	±0.0003	0.973	54
96 hours	0.109	12.220	—0.0186	0.0105	±0.0004	0.962	57

1 The weight figure used is that of the initial weight, *i.e.*, the weight of the mushrooms when freshly picked

2 See Fig. 3
Significant 't' ($p < 0.001$) in all equations

Texture and water loss

The relationship between the shear press reading and the initial weight[2] of mushrooms was highly significant ($p < 0.001$), even on day 5 (96 hours) when uncovered mushrooms had lost a large amount of moisture (Table II).

A plot of the shear press reading of mushrooms against their weight on any day gives a texture line for that particular day. Texture lines for covered and uncovered mushrooms for each day of the experiment are shown in Figs. 1 and 2. The lines are drawn using the initial mushroom weight.

Figs. 1 and 2 suggest that an initial toughening of both covered and uncovered mushrooms took place in the first 24 hours after picking followed by a temporary arrest in the second 24 hours. Toughening recommenced after 48 hours in covered mushrooms and continued to the end of the experiment (96 hours). In Fig. 2 the texture lines for uncovered mushrooms (24, 48, 72 and 96 hours) are superimposable.

The results of the paired mushroom experiment are shown in Table III. No relationship existed between the percentage loss in weight and the difference in shear press reading for paired mushrooms.

2 Initial mushroom weight is taken as the weight of the mushroom when freshly picked

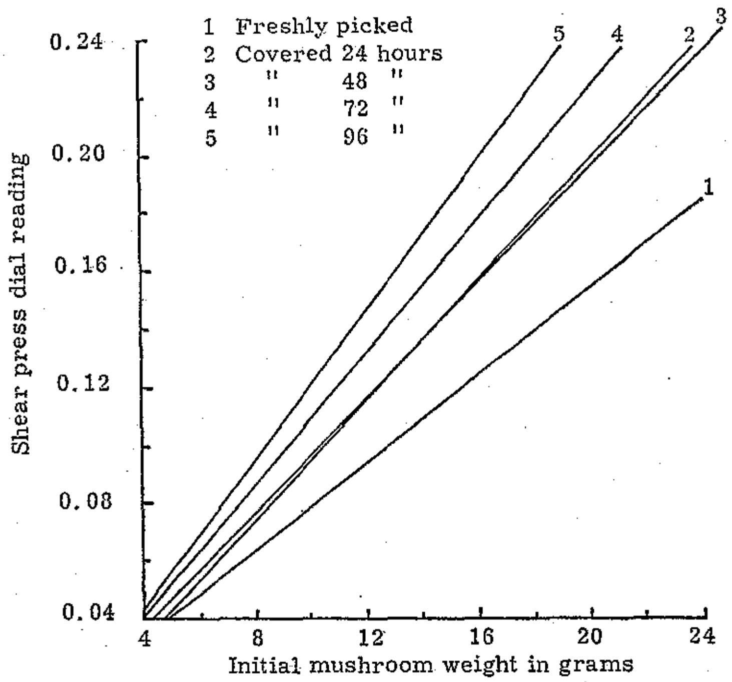

Fig. 1: Texture lines for covered mushrooms

TABLE III: Relationship between the difference in shear press reading and percentage loss in weight in covered (Resinite) and uncovered paired mushrooms

	Difference in shear press dial reading[1] (mean)	Percentage loss in weight (mean)	Constant	Regression coef	Standard error of (*b*)	Corr. coef	Degrees of freedom
	y	*x*	*a*	*b*	SE (*b*)	*r*	df
Covered 24 hours	0.043	4.474	0.0439	—0.0001	±0.0037	0.009	13
48 hours	0.034	4.632	0.1190	—0.0184	±0.0082	0.560	11
72 hours	0.052	8.788	0.0597	—0.0009	±0.0050	0.050	11
96 hours	0.062	9.589	0.1149	—0.0055	±0.0030	0.502	10
Uncovered							
24 hours	0.024	16.348	0.0659	—0.0028	±0.0011	0.481	21
48 hours	0.019	24.227	0.0059	—0.0006	±0.0004	0.370	14
72 hours	0.010	42.436	0.0031	—0.0015	±0.0008	0.436	16
96 hours	0.010	57.179	0.0089	0.00003	±0.0004	0.013	20

[1] See Fig. 3
All equations 't' non-significant

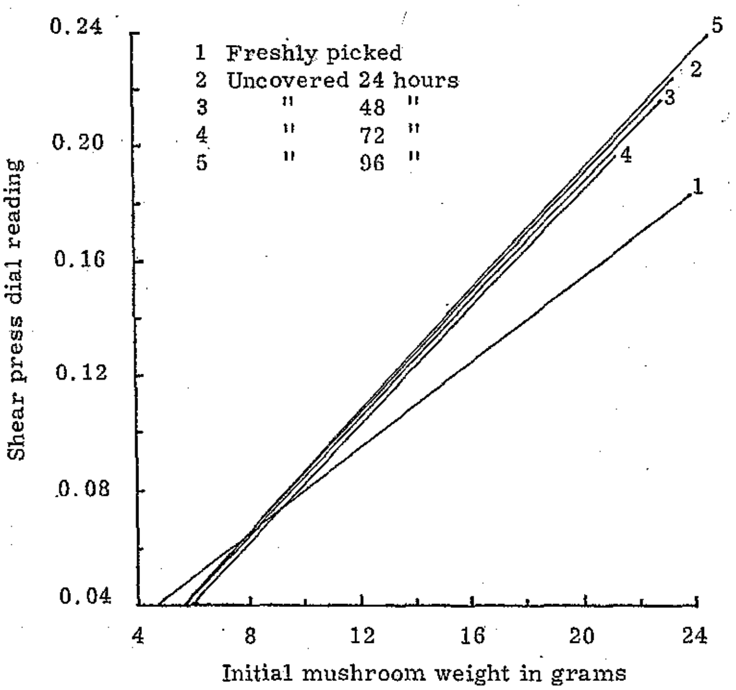

Fig. 2: Texture lines for uncovered mushrooms

Colour deterioration and water loss

Prepackaging with the film Resinite had a significant effect ($p < 0.001$) on the retention of whiteness and water in mushrooms (Table IV). Covered mushrooms had lost 18.8 percent of their original whiteness after 96 hours while uncovered mushrooms had lost 31.6 percent. The corresponding water losses were 10.8 and 68.3 percent. The ratios of percentage loss of whiteness to percentage loss of water were almost constant with time for covered or uncovered mushrooms (Table IV).

Reflectometer readings for freshly picked and 1-day-old mushrooms differed greatly even though the latter were still white. This showed that the reflectometer was capable of detecting the 'extra white bloom' of a freshly picked mushroom.

Antioxidant applications

Mushrooms treated by total immersion or spraying in any of the four antioxidant solutions and left uncovered deteriorated in 1 to 2 days when stored at 15° to 21°C. A large amount of the deterioration was caused by wrinkling due to water loss, although browning was also evident. Mushrooms, similarly treated and covered with Resinite, had a shelf life of 3 to 5 days. The shelf life of untreated covered and uncovered controls was 5 to 7 and 2 to 4 days respectively.

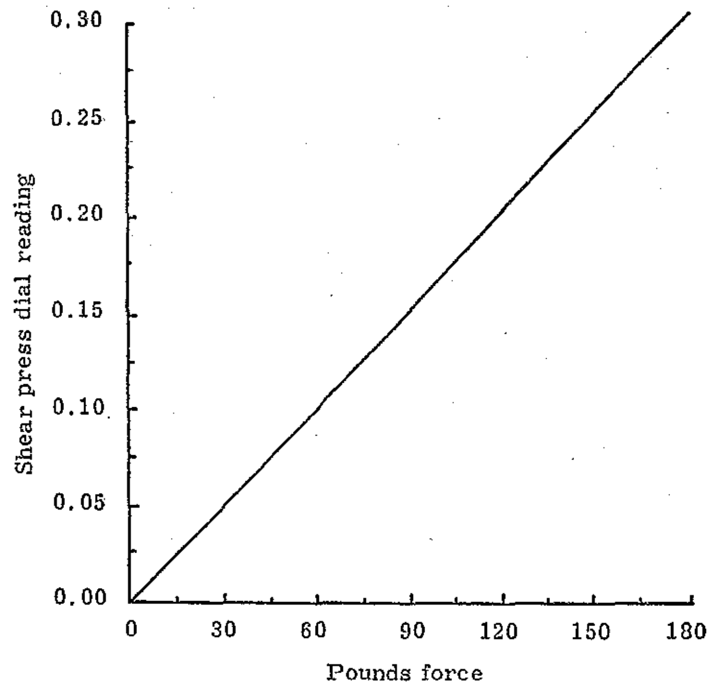

Fig. 3: Conversion chart: shear press dial reading to pounds force

Mushrooms washed by total immersion in antioxidant solutions deteriorated faster than those which were sprayed with the solution.

DISCUSSION

Packaging and shelf life

It is essential that films used for prepackaging mushrooms should have some degree of permeability to water vapour and have an anti-fogging agent incorporated, otherwise condensation and fogging will occur on the underside of the film which takes from the appearance of the pack. The short shelf life shown by mushrooms packed in containers covered with perforated films was probably due to excessive water loss. Other films such as polythene cause premature rotting of mushrooms largely due to impermeability to water vapour.

When mushrooms are transported in large open containers, vibrations from the vehicle cause brown marks on the cap of the mushrooms due to the release of polyphenol oxidase. These minute vibrations have an abrasive effect and may cause browning equal to that caused by extensive bumping or handling. In the prepack, however, the downward pressure of the film holds the mushrooms firmly together and reduces vibrations, thereby minimising browning. In addition, the artificial atmosphere within the prepack may slow down the action of the polyphenol oxidase.

Chemical changes which might have arisen in the mushrooms due to the artificial atmosphere within the pack were not investigated. Mushrooms were not stored at low temperatures (0° to 5°C) as one of the purposes of the experiment was to establish the shelf life of mushrooms under the adverse temperature conditions (15° to 21°C) likely to be encountered during transport.

Texture and water loss

The shear press and reflectometer were found suitable for measuring quality in mushrooms. In shear pressing peas (11), the shear press cell is normally filled with a known weight of peas. In the present study an attempt was made to shear press a known weight of chopped mushrooms. This proved impractical because of difficulties in standardising the preparation of the sample. However, it was found that when

TABLE IV: Colour deterioration and water loss in covered (Resinite) and uncovered mushrooms

		Percentage loss in whiteness	Percentage water loss	Percentage loss in whiteness / Percentage water loss
Covered	24 hours	7.7	4.1	1.88
	48 hours	12.0	6.3	1.93
	72 hours	15.2	10.1	1.54
	96 hours	18.8	10.8	1.73
	Mean	13.4	7.8	1.77
Uncovered	24 hours	13.9	21.4	0.66
	48 hours	22.3	33.8	0.67
	72 hours	26.2	51.2	0.52
	96 hours	31.6	68.3	0.47
	Mean	23.5	43.7	0.58
Means	24	10.8	12.7	1.27
	48	17.2	20.1	1.30
	72	20.7	30.6	1.03
	96	25.2	39.6	1.10
F-test: Covered vs. Uncovered (P)		***	***	***
Time (T)		***	***	NS
Interaction (P x T)		*	***	NS
Standard error (P)[1]		±0.5	±0.7	±0.06
(T)		±0.7	±1.0	±0.09
(P x T)		±1.0	±1.4	±0.12

[1] Standard error of treatment mean (df = 49)

whole mushrooms were shear pressed individually an excellent relationship was obtained between the shear press reading and initial mushroom weight.

One important aspect of the present study is the relationship of water loss to texture. As the texture lines in Fig. 1 show, the shear press readings of covered mushrooms increased during the experiment. This may have been caused by a toughening due to water loss, or some chemical change, or a combination of both. If the increased shear press reading was due to toughening caused entirely by water loss, a strong relationship should exist between the percentage loss in weight and the difference in shear press readings for paired mushrooms. Since no relationship was obtained (Table III), it is likely that chemical changes contributed to the increased toughness in mushrooms.

A large amount of toughening took place in covered and uncovered mushrooms during the first 24 hours after picking. In the case of covered mushrooms, there were two periods of toughening separated by an intermediate period of 24 hours when no change in texture took place. It was not possible to see if this intermediate period was present in uncovered mushrooms because the texture lines were superimposable, their 'true positions' being masked by the large water loss (Fig. 2). Fig. 2 suggests that no toughening occurred in uncovered mushrooms after 24 hours; however, when allowance is made for a large moisture loss, it can be assumed that uncovered mushrooms continued to toughen after the first 24 hours.

The texture of covered mushrooms changed visually after 48 hours, *i.e.*, the shear press was cutting mushrooms in 'cleaner' slices than when measurements were taken at 0 and 24 hours. This 'cleaner' slicing coincided with the onset of the second period of toughening which indicated that some chemical change might be taking place in the mushroom. Work on this aspect is being continued.

Colour deterioration

The ratios of percentage loss of whiteness to percentage loss of water were almost constant with time for covered or uncovered mushrooms. This suggested that water loss may be associated with loss of whiteness. The significant two factor interaction (P x T, $p < 0.05$) indicated that covered and uncovered mushrooms did not lose whiteness at the same rate (Table IV). A similar interaction ($p < 0.001$) occurred for loss of water.

Antioxidant applications

A combination of prepackaging and antioxidants did not prolong the shelf life of mushrooms. When mushrooms have been picked, further wetting seems irreversible, *i.e.*, it is difficult to dry the mushrooms properly again. This was probably the major factor in the deterioration of covered mushrooms which had been treated with antioxidant solutions.

Hughes (6) obtained good white colour retention for 5 days in mushrooms treated with thiol compounds, but his experiment was carried out using only tightly veiled mushrooms whereas the present experiment was done using tight and open-veiled mushrooms.

Antioxidant treatment of mushrooms on a commercial scale would require carefully controlled systems for washing and drying and may not be feasible in practice. Prepackaging of mushrooms, on the other hand, is an extremely simple procedure and can be carried out at the growing centre immediately the mushrooms are picked.

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