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Texture studies on mushrooms

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Summary. Measurement of texture is a useful quality control test for mushrooms. Results of these studies suggest that texture differences in mushrooms may be divided into primary and secondary differences. The former refer to differences caused largely by variation in the dry matter content of mushrooms, the latter to differences caused by variation in the nature of the dry matter content.

The shear press was used for measuring mushroom texture. Shearing mushrooms previously sliced with a household egg slicer gave more accurate results than shearing whole individual mushrooms. The relative precision of the shearing operation was the same for different weights of sample but increasing slice size had a slight positive effect on the shear press reading.

Taste panels were capable of detecting texture differences in cooked mushrooms which were also detected by the shear press.

Introduction

Texture, dry matter content and whiteness are three quality control tests that can be carried out on mushrooms. The latter two are straightforward and simple to assess; texture, however, is more involved and needs further investigation.

Texture studies on mushrooms have shown that mushrooms covered with a synthetic film continued to toughen for a period after harvesting (Gormley & MacCanna, 1967). Mushrooms were sheared individually on an Allo–Kramer shear press using a standard test cell. Initial weight plotted against shear press reading for a number of mushrooms on any particular day of the 5-day experiment gave a texture line for that day ($r > 0{\cdot}875$) (Gormley & MacCanna, 1967). Shearing mushrooms individually is time consuming and it was decided in the present study to shear mushrooms that have previously been sliced; a representative sample can be easily obtained and thus fewer shear press readings are required. Size of slice and variation in weight of material sheared were also studied.

Since mushrooms for shearing are weighed into the shear press cell it is necessary to find whether texture of mushrooms is related to both moisture and cellular material (dry matter) content. If texture is caused largely by cellular material the shear press value should be correlated with the dry matter as well as with the fresh weight.

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Shearing equal fresh weights of mushrooms, from growing treatments which give different moisture contents, may only show texture differences which are caused by variations in dry matter content. In this paper these are referred to as primary texture differences. However, other texture differences may be caused by variations in the nature of the cellular material and these are referred to as secondary texture differences. To obtain an indication of secondary texture differences it would be useful to express texture of mushrooms as the force required to shear mushrooms containing a certain weight of cellular material. The dry matter figure can be chosen arbitrarily, e.g. 3 g would be suitable since 35 g of fresh mushrooms (the fresh weight normally sheared) contain approximately 3 g of cellular material.

Experimental

Slice size and sample weight

Freshly harvested mushrooms (*Agaricus bisporus*) from the same growing treatment were sorted into sizes by weight, i.e. 4–6 g, 6–8 g, . . ., 18–20 g. Stipes were cut flush with the underside of the cap and the mushrooms in each group were sliced vertically with an egg slicer giving slices $\frac{3}{16}$ in. thick. Slices (35 g fresh weight) from each group were sheared on an Allo–Kramer shear press using the standard test cell (Kramer, Burkhardt & Rogers, 1951) to study the effect of slice size on the shear press value.

Batches of sliced mushrooms ranging in weight from 5 to 50 g (5 g increments) were sheared (fifteen readings each) to obtain the relative precision of the shearing operation at each weight.

Dry matter estimations

Two methods of measuring dry matter were compared for precision and convenience:

(1) Thirty mushrooms (stipes trimmed) were sliced with an egg slicer. Ten grams of slices were put in each of ten weighed dishes and dried in a vacuum oven at 70°C and 560 mmHg.

(2) One hundered grams of sliced mushrooms were blended with 100 ml of water for 3 min. Twenty sub-samples were removed, placed in dishes, and dried in a vacuum oven at 70°C and 560 mmHg. Most of the water had been previously removed by placing the dishes on a steam bath for 0·5 hr. The result was multiplied by two to account for the added water.

Texture and dry matter content

Three separate shearing experiments were carried out.

Experiment 1. Twelve samples of freshly harvested sliced mushrooms, from the same nitrogen growing treatment, were sheared to study the contribution of moisture and dry matter contents to texture. Samples weighing 10–50 g (5 g increments) were sheared in triplicate and three dry matter estimations were made. Correlations between shear press reading × dry matter content and shear press reading × fresh weight were obtained.

Experiment 2. Mushrooms from a watering trial and a storage trial were utilized to show that equal fresh weights of mushrooms (35 g) containing different dry matter contents gave different shear press values. It was necessary to combine mushrooms from the seven replications of the watering trial in order to obtain sufficient material for the shearing experiment.

Shear press readings and dry matter contents were carried out in triplicate on sliced mushrooms (35 g) from each treatment. Mushrooms from the water treatments were sheared 0·5 hr after harvesting. The experiment was replicated once.

Water treatments
(a) Compost containing five times its own weight of water (83·3%).
(b) Compost containing four times its own weight of water (80·0%).
(c) Compost containing three times its own weight of water (75·0%).
(d) Compost containing twice its own weight of water (66·6%).

Storage treatments
(a) Harvested mushrooms, covered and stored at 15–21°C for 24 hr.
(b) Harvested mushrooms, covered and stored at 15–21°C for 48 hr.
(c) Harvested mushrooms, covered and stored at 15–21°C for 72 hr.
(d) Harvested mushrooms, uncovered and stored at 15–21°C for 24 hr.
(e) Harvested mushrooms, uncovered and stored at 15–21°C for 48 hr.
(f) Harvested mushrooms, uncovered and stored at 15–21°C for 72 hr.

All mushrooms used in the storage part of the experiment were obtained from the same growing treatment. The term 'covered' mushrooms refers to 8–12 mushrooms in a Hartman Foodtainer tray 5½ × 5½ × ¾ in. covered with the synthetic PVC film Resinite. The term 'uncovered' mushrooms refers to 8–12 mushrooms in a similar unwrapped container.

Experiment 3. Six samples of sliced mushrooms (15–40 g; 5 g increments) from each of twelve different treatments were sheared to examine the linearity of the relationship between shear press reading and fresh and dry weights of sliced mushrooms. The different treatments used are listed below.

(a) Nitrogen supplementation treatment (cottonseed meal).
(b) Nitrogen supplementation treatment (dried blood).
(c) Harvested mushrooms, uncovered and stored at 15–21°C for 24 hr.
(d) Harvested mushrooms, uncovered and stored at 15–21°C for 48 hr.
(e) Harvested mushrooms, uncovered and stored at 15–21°C for 72 hr.
(f) Harvested mushrooms, prepacked (Resinite) and stored 15–21°C for 24 hr.
(g) Harvested mushrooms, prepacked (Resinite) and stored 15–21°C for 48 hr.
(h) Harvested mushrooms, prepacked (Resinite) and stored 15–21°C for 72 hr.

(i) Compost containing five times its own weight of water.
(j) Compost containing four times its own weight of water.
(k) Compost containing three times its own weight of water.
(l) Compost containing twice its own weight of water.

Texture of cooked mushrooms

Mushrooms from different growing treatments, harvested 48, 24 and 0·5 hr, were sliced with a household egg slicer and simmered gently with margarine in three separate dishes for 20 min. Prior to cooking, the mushrooms were stored at 15–21°C in Hartmann Foodtainer dishes $5\frac{1}{2} \times 5\frac{1}{2} \times \frac{3}{4}$ in. wrapped with the synthetic film Resinite. Texture and dry matter estimations were made at harvest time and again before cooking. After cooking the three samples were allowed to drain on wire sieves and were submitted to a six-member taste panel. The panel was asked to rate texture only. The most recently harvested sample (0·5 hr) was offered as standard (0) and also as a coded sample. Increasing chewiness was given as +1, +2 and decreasing chewiness as −1, −2. The panel was repeated once.

After draining for 10 min triplicate samples (35 g) of the cooked mushrooms from each of the sieves were removed and sheared.

Results and discussion

Slice size and sample weight

Large mushroom slices gave a higher shear press reading than small slices (Table 1). Therefore, when shearing a sample it is important to mix the slices thoroughly before taking the 35 g sub-sample.

TABLE 1. The effect of slice size on the shear press reading using a 35 g sample

Slice size (mushrooms grouped by weight) (g)	Shear press reading (lb force) (mean of five readings)
4–6	122
6–8	114
8–10	129
10–12	136
12–14	140
14–16	143
16–18	144
18–20	141

The relative precision of the shearing operation using different sample weights was calculated from equation (1) (Kramer & Twigg, 1962):

$$n = \left(\frac{ks}{p}\right)^2, \qquad (1)$$

where n = relative precision;
s = standard deviation;
k = 3 for 99% assurance; and
p = 0·01 for 99% assurance.

A relative precision of three was obtained for the different sample weights tested. Thirty five grams was chosen for most of the shearing operations because this quantity filled the standard test cell to about three-quarters of its capacity and ensured a good subsample size.

Dry matter estimations

Of the two methods compared the blender method gave the more precise results (Table 2) and was also the more convenient. It is essential that the sub-sample removed contains added water and fresh mushrooms in the ratio 1 : 1. This ratio is obtained provided the sub-sample is taken rapidly after blending. Multiplication of the weight of dried residue by two gives the dry matter content. If the mushrooms contain more than 10% dry matter it is sometimes necessary to blend one part mushroom with two parts water in order to obtain a blend of the desired consistency for sub-sampling.

TABLE 2. Comparison of two methods for estimating the dry matter content of mushrooms

Method	Mean dry matter (%)	Standard error	Time for drying at 70°C and 560 mmHg
(1) Drying slices directly (ten estimations)	7·395	±0·367	12 hr
(2) Drying blended slices (twenty estimations)	7·586	±0·064	5 hr

Texture and dry matter content

Experiment 1. A high linear correlation (r = 0·982) was obtained when fresh mushroom sample weights (10–50 g, 5 g increments) were correlated with the corresponding shear press readings. The dry weights and water contents associated with the above fresh weights gave correlation coefficients of 0·979 and 0·991, respectively, when correlated with the shear press values. It was hoped at this stage to obtain partial correlation coefficients for dry weight × shear press and water content × shear press and thus have an indication of the relative contributions of cellular material and water content (associated with cellular material) to the overall texture reading. However, the partial correlation coefficients could not be calculated because of the high relationship between dry matter and water contents ($r = 0·988$).

Experiment 2. Equal fresh weights (35 g) of mushrooms from a watering trial and a storage trial gave different shear press readings (Tables 3 and 4). Those mushrooms containing the highest dry matter content also had the highest shear press reading (Tables 3 and 4) which suggests that the higher the ratio of cellular material (dry matter) to water content, the higher the shear press reading.

The results (Table 3) show that the texture of mushrooms from different water treatments is quite similar if the results are calculated on a dry weight basis. When calculated on a fresh weight basis, however, texture differences do exist. This suggests that these differences are largely dependent on variations in the dry matter content of the 35 g samples sheared and can be called primary texture differences.

Previous work has shown that covering harvested mushrooms with a synthetic film reduces water loss and causes the mushrooms to toughen during storage (Gormley & MacCanna, 1967). Texture differences are obtained for covered mushrooms when the shear press readings are taken either on a fresh weight or dry weight basis (Table 4). Since equal dry weights give different shear press values this suggests that the nature of the cellular material is changing during storage. Texture differences due to changes in the nature of the cellular material can be called secondary texture differences.

TABLE 3. The effect of different water levels in the growing compost on the dry matter content and texture of mushrooms

Weight of water in compost (%)	Dry matter (%)	Dry weight §	Shear press reading† (lb force)	Shear press reading per 3 g dry weight‡
83·3	9·45	3·31	138	123
80·0	8·69	3·04	126	124
75·0	9·06	3·17	137	130
66·6	10·76	3·77	159	126
F-test (treatments)	***	***	***	N.S.
SE ($df = 3$)	±0·0493	±0·0185	±1·2750	±1·2250

† Shear press reading for 35 g fresh weight.
‡ Obtained by interpolation.
§ Dry weight corresponding to 35 g fresh weight.

*** Significant (P=0·001).
N.S., Not significant.
SE, Standard error.

In the case of uncovered mushrooms large texture differences were obtained on a fresh weight basis but only very slight differences on a dry weight basis (Table 4). This suggests that texture differences for uncovered mushrooms are primary texture differences caused mainly by variation in dry matter content due to the moisture losses taking place during storage. It must be assumed, however, that the moisture content does contribute to some extent to the texture reading because of its effect on cell turgor pressures. The loss of moisture, therefore, in uncovered mushrooms should cause a reduction in the shear press reading (expressed on a dry weight basis) with time. Since no reduction in shear press reading was observed it is possible that secondary texture differences existed and their positive effect on the shear press reading was counterbalanced by the negative effect caused by moisture loss.

The shear press readings are adjusted to a common denominator (Tables 3 and 4), i.e. 3 g dry weight, by approximation or interpolation. The approximation method is based on the fact that the texture line for shear press reading × weight of material sheared (either fresh weight or dry matter basis) is linear and almost goes through the origin. Hence, as an approximation, it suffices to divide the shear press reading by the dry weight and multiply by three. The interpolation method is more accurate and is again based on the fact that texture lines for all treatments tested were linear (see Experiment 3).

TABLE 4. The effect of different storage treatments on the dry matter content and texture of mushrooms obtained from the same growing treatment

Storage treatment	Dry matter (%)	Dry weight §	Shear press reading† (lb force)	Shear press reading per 3 g dry weight‡ (lb force)
Covered 24 hr	7·62	2·67	132	149
48	7·68	2·69	156	170
72	7·56	2·65	172	194
Uncovered 24 hr	9·86	3·45	170	152
48	11·04	3·86	198	151
72	12·15	4·25	221	157
F-test for two factor interaction	***	***	*	*
SE (*df* = 5)	±0·18	±0·02	±1·41	±4·58

† Shear press reading for 35 g fresh weight.
‡ Obtained by interpolation.
§ Dry weight corresponding to 35 g fresh weight.

* Significant (P=0·05).
*** Significant (P=0·001).
N.S., Not significant; SE, standard error.

Experiment 3. Six batches of mushrooms, from each of twelve treatments, were sheared to examine the linearity of the relationship between weight of mushrooms sheared and the shear press value. Twenty four texture lines (two for each treatment) were drawn by plotting both the fresh weights and the corresponding dry weights against the shear press readings. These relationships were linear and correlations between weight of material sheared and shear press reading were $\geqslant 0{\cdot}989$ excepting one which was 0·971. It will suffice in future experiments to shear only two mushroom samples (25 and 40 g) in order to obtain a texture line. The corresponding texture line for dry weight versus shear press reading can be readily obtained and the shear press reading equivalent to 3 g dry weight calculated by interpolation.

Texture of cooked mushrooms

In all but one case the relative texture differences between batches of mushrooms were not changed by cooking. Absolute texture readings fell by 32·2–48·7% depending on the texture of the mushrooms before cooking (Table 5). The mushrooms used were from various growing treatments and had different shear press values when harvested. However, those stored for 48 hr were tougher than those stored for 24 hr irrespective of the texture when freshly harvested. The panels were carried out on consecutive weeks but were not replicated each day because of difficulties in obtaining cooking facilities. The panel members rated the two batches of samples in the same

TABLE 5. Taste panels on cooked mushrooms from different storage treatments

Storage treatment	Shear press reading when freshly harvested‡ (lb force)	Shear press reading before cooking‡ (lb force)	Shear press reading after cooking† (lb force)	Average panel score for texture	Loss in shear press reading on cooking (%)
Panel 1					
Covered 48 hr	110	164	84	−1·17	48·7
24 hr	124	154	95	+0·33	38·3
Freshly harvested	134	134	90	−0·33	32·8
Panel 2					
Covered 48 hr	128	166	102	+0·67	38·7
24 hr	126	156	86	+0·50	45·0
Freshly harvested	106	106	72	0·00	32·2

† Reading for a 35 g sample on a cooked weight basis.
‡ Reading for a 35 g sample on a fresh weight basis.

order as the shear press. The reliability of the panels is borne out by the texture scores given to the coded sample of the standard, i.e. −0·33 (downgraded) in panel one and 0·00 (correct score) in panel two. The percentage loss in shear press reading on cooking is greatest for the stored mushrooms. Toughening during storage is probably caused by changes in the nature of the cellular material and cooking seems to nullify this process to some extent. Adhering margarine on the 35 g mushroom slices sheared after cooking also lowers the shear press value since the 35 g sample contains less mushroom tissue. In panel one the mushrooms covered for 48 hr were the toughest before cooking and softest after cooking. This may have been due to the fact that they had a low dry matter content when harvested as indicated by the shear press reading of 110 lb.

Conclusion

This investigation shows that dry matter contents and textural properties of mushrooms vary under different conditions. Tests for these characteristics should be part of any quality control programme. Shearing a given fresh weight of sliced mushrooms gives an incomplete picture of texture and it is necessary to express texture differences on a dry weight basis as well; this gives the opportunity to distinguish between primary and secondary texture differences. Secondary texture differences seem to develop to the greatest extent in covered (prepacked) mushrooms and this may be due to certain properties of the covering film, e.g. its ability to reduce water loss and modify the atmosphere in the prepack.

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