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Flavor and Texture of the Common Mushroom, *Agaricus bisporus*

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ABSTRACT: Flavor and texture of a number of commercial strains of *A. bisporus* were analyzed, both sensorily and instrumentally. Volatile and non-volatile compounds contributing to the flavor perception were analyzed by means of dynamic headspace GC/MS and biochemical assays. Instrumental texture and analysis of mushroom tissue was performed using an Instron Testing device. Differences between individual strains were small with respect to flavor. This was due to significant loss of (non) volatile compounds during the microwave-heating treatment, as demonstrated by GC analysis and analysis of glutamic acid. With respect to the mouthfeel properties size-differences were observed for the firmness of U1 mushrooms, whereas small-sized brown mushrooms had high scores for toughness. On the basis of force/displacement curves, it is suggested that the texture differences between stored and fresh mushrooms might be related to toughness rather than to firmness.

1 INTRODUCTION

The cultivation, trade and processing of common mushrooms (*Agaricus bisporus*) are economically important horticultural activities in the European Union and the United States. The consumption of fresh mushrooms has increased in recent years along with an increased emphasis on improving the quality and availability of fresh produce. A key factor in increasing the sale of fresh mushrooms is the improvement of the quality available to the consumer. Therefore, practices to gain a longer shelf-life and a better quality have been studied to improve the point-of-sale quality.

Whiteness is considered to be one of the most important aspects of fresh mushrooms. Mushrooms with discoloration are judged to be of low quality and hence low commercial value (Burton 1988).

In addition, flavor represents a very important quality attribute contributing to the widespread consumption of edible mushrooms. However, the genetic basis of the currently used commercial strains in The Netherlands is relatively small, leading to little variation. A deepened insight in the biochemical processes, and the processing conditions that influence flavor and texture of mushrooms will enable a stronger positioning of high-quality mushrooms.

The research reported herein was designed to examine the organoleptic evaluation of several commercial strains of *A. bisporus*, along with chemical analysis of the odor, flavor and texture. Differences between strains and developmental stages were studied.

2 MATERIALS AND METHODS

2.1 *Material and sample preparation*

Different strains of *A. bisporus* were purchased from commercial growers and local markets. The following strains were used: U1 (white), biologically grown and conventionally cultivated as well as cave-grown, Eurosemie 280 (white), and the brown strains Amycel 2400 and Le Lion C9. The mushrooms were analyzed both raw and processed. Processing was performed by applying microwave heating (700 W, 3 min) to a fixed amount of mushrooms (400 g) in a closed dish with 10 ml of water. For instrumental flavor analysis, mushroom slices were frozen in liquid nitrogen and either vacuum freeze-dried for biochemical analysis or, after addition of saturated $CaCl_2$ to prevent enzyme activity, homogenized under liquid nitrogen for GC analysis.

2.2 *Sensory analysis*

A descriptive test (Stone and Sidel 1993) was used to evaluate odor attributes of raw and heated mushrooms, as well as flavor (taste and aroma) and mouthfeel of heated mushrooms. Training of the panel, consisting of 21 judges aged from 25 to 45, was executed in different phases. For odor and flavor assessment, 15 chemicals were sniffed and described in the first phase. Successively, the same chemicals were evaluated, using a checklist including the compiled descriptor to train the odor recognition of the assessors. Mouthfeel assessment was trained by providing products,

demonstrating certain mouthfeel characteristics, to the panel. In the next sessions, an assortment of mushroom varieties was offered to the panel, to provide a wide range of sensory properties to be expected in the mushrooms. These varieties were also used for training of the intensity scaling of the sensory attributes. Finally, the samples were rated on a line-scale.

For odor assessment, all samples, both raw and heated, were presented in aluminum foil covered jars. For flavor and mouthfeel evaluation, only microwave-heated mushrooms were presented to the panel. Sensory analysis was performed at room temperature in isolated air-conditioned booths with slight positive pressure.

2.3 *Instrumental analysis*

Dynamic headspace isolation of volatile compounds was performed according to Macleod and Ames 1986, using Tenax TA as adsorbent. Homogenized samples (3 g) were flushed with 30 $ml.min^{-1}$ purified nitrogen, at 35°C. Volatiles were desorbed from the Tenax tubes (Tekmar 6016 desorber/autosampler, Interscience, The Netherlands) and injected in a capillary Supelcowax 10 column (30 x 0.25 mm, d_f=0.25 µm). The gas chromatograph (Fisons 8000, Interscience) was equipped with a FID. The GC/MS (Carlo Erba, Mega 3600, QMD 8000, Interscience) was equipped with a thermal desorption unit (Tekmar 510, Interscience). For both devices, thermal desorption conditions (10 min at 200°C) and GC column conditions (from 40 to 150 °C with 2 $°C.min^{-1}$, followed by 10 $°C.min^{-1}$ to 250°C) were identical. Electron impact mass spectral analysis was carried out at 70 eV.

Concentrations of glutamate, urea and ammonia were determined enzymatically following standard procedures (Boehringer 1989).

Texture analysis was performed using an Instron Universal Testing device. Force/displacement curves have been generated by compressing radial discs from the pileus with a diameter of 8 mm and a height of 5 mm.

2.4 *Data analysis*

Principal Component Analysis (PCA) and/or analysis of variance (ANOVA) were performed to interpret the data (Piggott and Sharman 1986).

3 RESULTS AND DISCUSSION

3.1 *Flavor*

Eighteen odor attributes were generated for sensory evaluation of several mushroom varieties. Raw mushrooms were mainly characterized by the

attributes mushroom, musty, earthy, metallic, sweet, floral and herbal. A minimal processing treatment (short microwave heating) strongly affected the score ratings. These heated samples were mainly characterized by the odor attributes mushroom, musty, sweet and bouillon/meaty. For the organoleptic evaluation of taste, aroma and texture, only heated mushrooms were presented to the panel, because of possible health effects of agaritin, a constituent of mushrooms (Toth 1995). Comparison of steaming, cooking and microwave heating of mushrooms indicated better quality preservation after microwave heating. For these microwave-heated mushrooms, differences were only observed for sweetness, respectively mushroom aroma, sweet aroma and bouillon/meaty aroma. The observed differences between strains were very small. Brown mushrooms were characterized by low scores for sweetness compared to the white strains. White cave-grown mushrooms had higher scores for sweet aroma and bouillon/meaty aroma.

The above indicated loss of organoleptic perceived flavor after a short heating treatment of mushrooms is supported by GC analysis of the volatiles. In raw U1 mushrooms 25 volatile compounds were detected, of which hexanal and 1-octen-3-ol had the highest intensities. The presence of these compounds is very probably due to enzymatic breakdown of linoleic and linolenic acid. Short microwave heating of mushrooms strongly reduced the intensity of many volatiles, except for benzaldehyde and benzylalcohol (Table 1). These latter compounds strongly increased after heating, due to Strecker degradation of phenylglycine (Whitfield 1992). The frequently observed compound 1-octen-3-one, which has a boiled mushroom/metallic note, has not been detected, neither in raw nor in heated samples. This might be due to enzymatic reduction to 1-octen-3-ol or 3-octanon (Chen and Wu 1984).

Since most fresh mushroom volatiles are readily lost during heating as described above, the flavor of heated mushrooms will mainly depend on volatiles generated from cooking or on the presence of non-volatile compounds. Therefore, concentrations of urea, ammonia and glutamatic acid were determined. For glutamic acid, which is thought to contribute significantly to the flavor intensity of mushrooms (Dijkstra and Wikén 1976), differences were observed between both developmental stages and various strains (Fig. 1). ANOVA-analysis demonstrated higher glutamate levels for both raw and heated mushrooms of the white strains, compared to the brown varieties. Differences were also observed between different developmental stages. Applying short microwave heating to the mushrooms clearly decreased the glutamate levels, whereas ammonia and urea concentrations increased. The latter increased probably reflected protein degradation.

Table 1. Changes in the composition of volatile compounds, isolated by dynamic headspace analysis, of microwave-heated mushrooms compared to raw mushrooms. Presented are changes in average GC-peak areas of the most important compounds of different strains of *A. bisporus*, respectively Eurosemie 280 (W2; white), U1 (W3; white), Amycel 2400 (B1; brown) and Le Lion C9 (B2; brown).

Compound	Kovats indices	Odors	W2	W3	B1	B2
Hexanal	1095	Freshly cut grass	↑*	↓	n.s.	↓
Heptanal	1180	Waxy, green, grassy	n.s.	↓	n.s.	n.s.
3-octanone	1242	Sweet, musty, floral, fruity	↓	↓	↓	↑
1-pentanol	1245	Rubbery, harsh, alcoholic	↑	↓	n.s.	↓
Octanal	1277	Floral, fruity, citrus, orange	↓	↓	↓	↓
2-heptenal	1315	Pungent, green, grassy	n.s.	↓	↓	↓
1-hexanol	1346	Fruity, herbal	↓	↓	↓	↓
1-octen-3-ol	1446	Mushroom	↓	↓	↓	↓
Benzaldehyde	1519	Almond, sweet, nuts	↑	↑	↓	↓
Benzyl alcohol	1865	Chemical, vase water	n.s.	↑	↑	↑

*↑, ↓, n.s.: significant ($P<0.05$) increase, respectively decrease or no change in average GC-peak area.

3.2 *Texture*

PCA analysis was carried out on mean scores of the mouthfeel attributes; 88% of the variance in the data was explained by two principal components (PCs; Fig. 2). The mouthfeel attributes toughness and (difficult) splittability were positively correlated; they were negatively correlated with firmness. ANOVA-analysis ($P<0.05$) showed that large, white mushrooms of strain U1 had the highest firmness, whereas the small-sized brown Amycel 2400 mushrooms were tough and difficult to split. No significant differences in mouthfeel attributes were observed between small, medium and cave-grown white U1 mushrooms.

Since texture is an important aspect of the keeping quality of mushrooms, considerable attention has been put on developing instrumental methods to assess firmness and toughness of mushrooms. However, texture measurements during mushroom maturation, as well as during postharvest storage have been hampered by morphological/anatomical differences in the mushroom tissue occurring during development. Consequently, designing standard methods by selecting discs from representative parts of the fruiting body, as well as discrimination between firmness and toughness, is important (McGarry and Burton 1994). Force/displacement curves, using an Instron Testing device, have therefore been generated from mushrooms in different developmental stages (Fig. 3). The compression and displacement before the yield point were not different in mushrooms of developmental stage 2 and 3. These parameters are thought to represent firmness and crispiness of the tissue. The

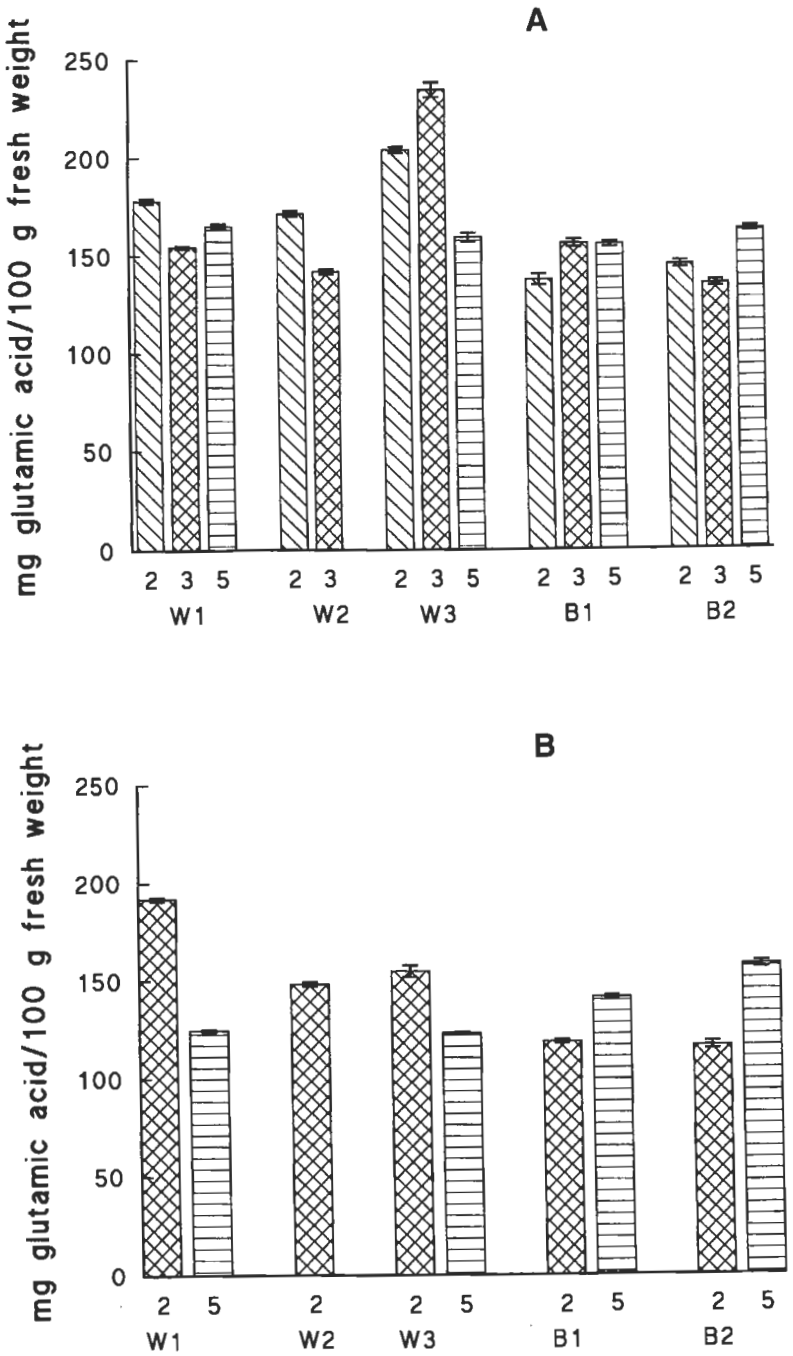

Figure 1. Levels of glutamic acid at different developmental stages (2, 3, 5) in different strains of raw (panel A) and microwave-heated (panel B) mushrooms. The strains used, were: white strains of U1 (both biologically grown (W3), as well as conventionally cultivated (W1)), Eurosemie 280 (W2), respectively brown strains of Amycel 2400 (B1) and Le Lion C9 (B2).

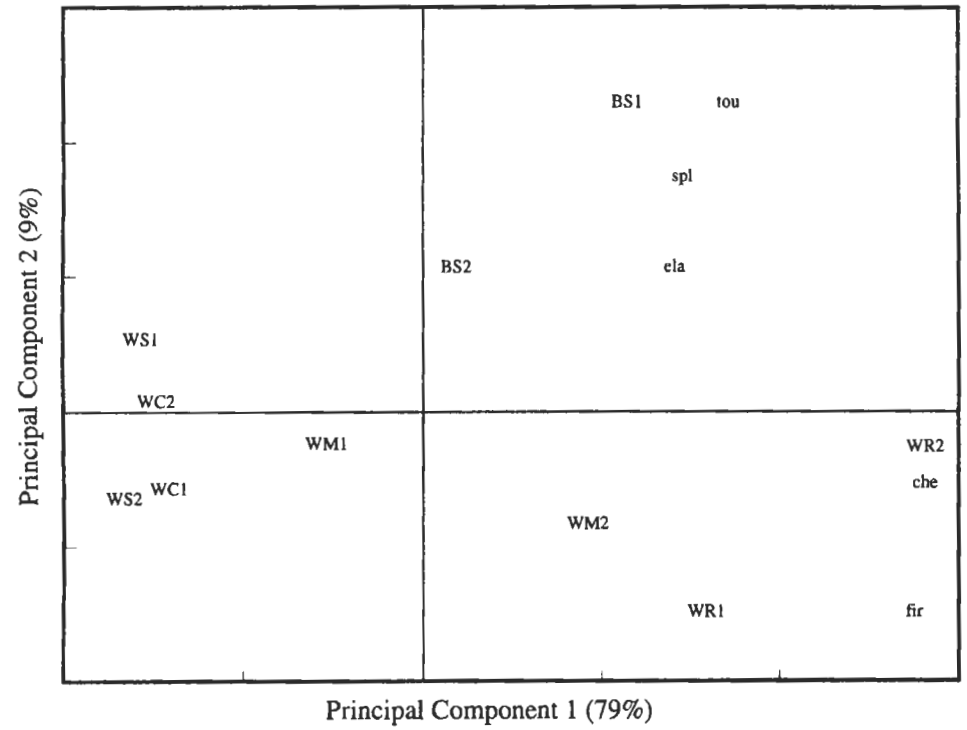

Figure 2. PCA sample scores and loadings of mouthfeel attributes of microwave-heated mushrooms. The strains used, were: white U1 mushrooms of small (WS), medium (WM) or large (WL) size or cave-grown (WC), respectively small-sized brown Amycel 2400 mushrooms (BS). The attributes used were toughness (tou), splittability (spl), elasticity (ela), chewiness (che) and firmness (fir).

curve after the yieldpoint was different for both developmental stages, which might be indicative for differences in toughness.

Mushrooms stored at 1 °C under low relative humidity (RH of 90%) lost about 7% of their weight (Table 2). However, the slope and compression before the breakpoint were not different from the values of fresh mushrooms or from mushrooms that were stored at high RH (>97%). But the load at the yield point and the area until the yield point were different between fresh and stored mushrooms. These observations suggest differences in toughness between stored and fresh mushrooms, rather than distinctions in firmness. The values of these instrumental texture parameters are now to be correlated with the mouthfeel assessments of the sensory panel, to describe and quantify the various textural properties of mushrooms.

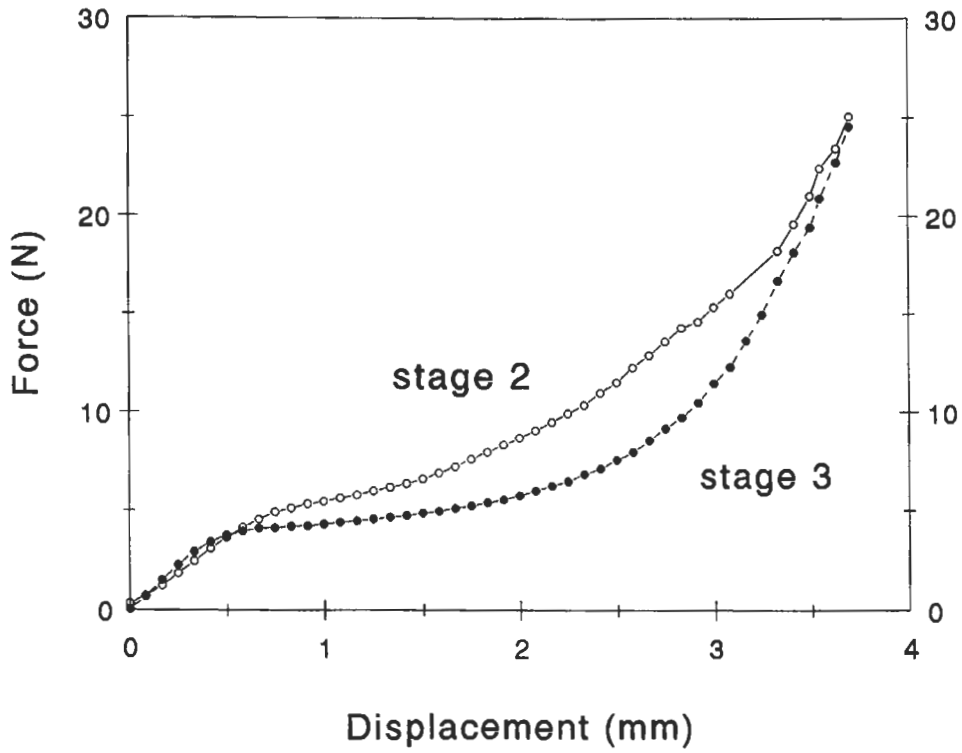

Figure 3. Compression of radial discs from the pileus of Amycel 2400 mushrooms, at the developmental stages 2 and 3.

Table 2. Texture parameters after compression with an Instron Testing device of mushrooms that were stored at 1 °C at high (>97%) or low (90%) relative humidity (RH; n=10 to 20).

	Fresh mushrooms on day 0	Stored at high RH on day 5	Stored at low RH on day 5
Weight loss (%)	—	1.7 ± 0.2	7.0 ± 1.0
1st slope N/mm	8.65 ± 1.86	9.20 ± 1.42	9.25 ± 0.87
Compression at 2N mm	0.24 ± 0.01	0.23 ± 0.03	0.22 ± 0.02
Compression at 3N mm	0.36 ± 0.02	0.34 ± 0.05	0.33 ± 0.03
Compression at 1st yieldpoint mm	0.40 ± 0.04	0.48 ± 0.05	0.50 ± 0.04
Load 1st yieldpoint N	3.22 ± 0.19	3.99 ± 0.28	4.51 ± 0.32
Area 1st yieldpoint mJ	0.68 ± 0.10	0.82 ± 0.13	1.11 ± 0.16

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