J Wood Sci (2005) 51:628–633
DOI 10.1007/s10086-004-0689-0

ORIGINAL ARTICLE

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The smell and odorous components of dried shiitake mushroom, *Lentinula edodes* II: sensory evaluation by ordinary people

Received: October 22, 2004 / Accepted: November 26, 2004

Abstract This study is part of an effort to improve the quality of dried shiitake mushrooms [*Lentinula edodes* (Berk.) Pegler], in accordance with consumer preference, and deals with a preference survey using questionnaires combined with sensory evaluation. The smell was evaluated using powdered dried shiitake mushrooms. Age, original preference (OP), sex, sensory intensity (SI), hedonic preference (HP), and sample amount were set as parameters. About 70% of panelists liked dried shiitake mushrooms. There were significant correlations among age, OP, and SI. There was also a significant correlation between OP and HP, but no significant correlation between SI and HP. However, when the panelists were classified by OP, there was an optimal value between SI and HP for likers and neutralists. The calculated optimal concentration of dried shiitake mushrooms for likers and neutralists ranged widely. On the other hand, there was a significant negative correlation between SI and HP for dislikers, and their HP decreased according to the increase in the amount of the substance. The results showed that different concentrations of odorous components in dried shiitake mushrooms were needed to satisfy different consumer preferences.

Key words Sensory evaluation · Dried shiitake mushroom · Hedonic preference · Sensory intensity

Introduction

There are many factors that determine consumer preferences in assessing the quality of foods,[1] and one of the most important factors is smell.[2–5] Shiitake mushroom [*Lentinula edodes* (Berk.) Pegler] has been eaten since ancient times, and is one of the most popular edible mushrooms in Japan and other parts of the Far East. Dried shiitake mushroom has been especially appreciated, because it has a characteristic smell, which is absent in fresh shiitake mushroom. Mushrooms are considered as a kind of luxury grocery item; and the characteristic smell of dried shiitake mushrooms is one of the main factors used for evaluation. Therefore, to increase their consumption, it is desirable to provide dried shiitake mushrooms having the smell preferred by consumers.

Preferences for foods vary with consumer age, sex, and region.[6–8] For example, it is generally recognized that older consumers like dried shiitake mushrooms, but younger consumers dislike them. However, consumer preferences for dried shiitake mushrooms have not been surveyed yet; so even this common assumption has not been scientifically established.

Nevertheless, past improvements of dried shiitake mushrooms have been made on the shape of the fruiting body, the amount of production per log, and so on, because dried shiitake mushrooms are mostly evaluated in markets by their shape and not by qualities such as smell, taste, and texture.

Of the odorous compounds, 1,2,4,5,6-pentathiepane, commonly known as lenthionine, has been reported as a main compound of dried shiitake mushrooms,[9,10] although many other substances such as sulfur-containing substances and alcohols[11–15] are also present. In the previous report,[16] the authors found that not only lenthionine but also 1,2,4-trithiolane and 1,2,4,6-tetrathiepane affected the characteristic smell of dried shiitake mushrooms. Moreover, it was clarified that 1,2,4-trithiolane could serve as an indicator to estimate the smell.[16]

The authors aimed to improve the quality of dried shiitake mushrooms in accordance with consumer preferences. However, there is no index of the preference for the smell of dried shiitake mushrooms. Therefore, this study of consumer preferences used questionnaire data combined with sensory evaluation tests to elucidate the relationship

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between the smell of dried shiitake mushrooms and consumer preference.

Materials and methods

Preparation of dried shiitake mushrooms

The preparation of dried shiitake mushrooms was conducted using the same method as in the previous report.[16] A strain of shiitake mushroom, Forestry Mycology Code 208, derived from stock cultures of the Mushroom Science Laboratory, Forestry and Forest Products Research Institute, was used. The average yield of fruiting body was 183 g (wet weight) per 1 kg of sawdust medium.

Analysis of sensory intensity and sensory evaluation

Samples of dried shiitake mushroom powder (10, 100 mg, and 2 g) were packed in opaque 200-ml plastic bottles with lids. The bottles were marked with colored tape. The samples were equilibrated at room temperature before each session, which was performed in a room ventilated with fresh air.

Before the evaluation, the panelists were asked for their sex, age, and their original preference (OP) for dried shiitake mushrooms. The ranking of their OP was one of the following: −3 extreme dislike, −2 dislike, −1 slight dislike, 0 neutral, 1 slight like, 2 like, and 3 extreme like.[17] In addition, the panelists were instructed and a demonstration was given on how to bring the sample near the nose, about 2 cm from the nose to the mouth of the bottle, and how to open the lid and close the lid immediately after smelling. The panelists were offered each sample in random order. They evaluated each sample once, and entered the answers in the corresponding place on the questionnaire sheet. They estimated sensory intensity (SI) and judged their hedonic preference (HP) for the sample. The ranking of the SI was one of the following: 0 almost no smell, 2 very weak smell, 4 weak smell, 6 moderate smell, 8 strong smell, 10 extremely strong smell.[17] The ranking of their HP for the sample was the same as that of their OP.

The panelists consisted of 335 assessors: students of Yokosuka Civic Nagai Elementary School, Miura Civic Misaki Junior High School, Kanagawa Prefectural Ohgusu Senior High School, and Yokohama National University; employees of the Forestry and Forest Products Research Institute of Japan, and retired employees in Fukuoka Prefecture (Table 1).

Analysis of odorous compounds

The analysis was conducted using the same methods as described in the previous report.[16] The amounts of aromatic compounds, 1,2,4-trithiolane, 1,2,4,6-tetrathiepane, and lenthionine were 62.9, 6.9, and 37.5 μg/g, respectively.

Table 1. Breakdown of panelists

Age class	Male	Female	Total
10–19	39	46	85
20–29	22	35	57
30–39	21	23	44
40–49	24	23	47
50–59	20	26	46
60+	26	30	56
Total	152	183	335

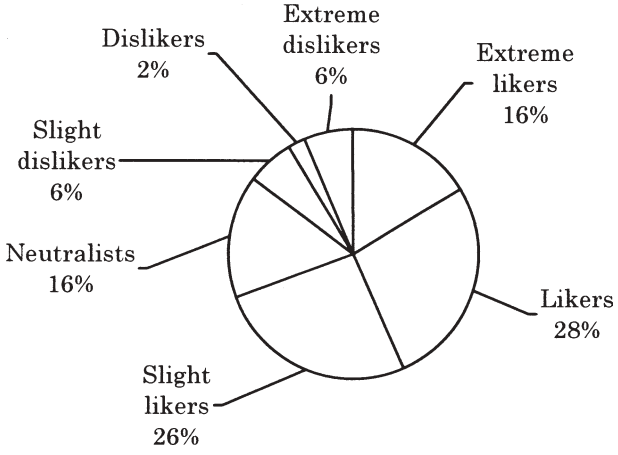

Fig. 1. Breakdown of original preference for dried shiitake mushroom

Calculations

All statistical treatments were conducted using SPSS for Windows version 11.0 J (SPSS).

Results and discussion

Overview of the questionnaires

The relative occurrences of the OP classifications for dried shiitake mushrooms are shown in Fig. 1. The relative occurrence for "extreme dislike" was 6.3%, "dislike" 2.4%, "slight dislike" 6.0%, "neutral" 16.1%, "slight like" 26.0%, "like" 26.9%, and "extreme like" 16.4%. The combined relative occurrences for likers was 69.3% and that for dislikers 14.6%, showing that people generally like dried shiitake mushrooms.

To analyze the questionnaires rigorously, the authors checked the values and omitted some data. There was a broad distinction between the 10-mg and 2-g bottled samples, and the SI of the 2-g sample was apparently stronger than that of the 10-mg sample, although some panelists reported the reverse answer.

There were many parameters in the questionnaires: sex, age, OP, sample amount of dried shiitake (SA), SI, and HP. To clarify the relations among these parameters, Spearman rank order correlation coefficients (ρ) between age class (AC), OP, SA, SI, and HP were calculated

(Table 2). The difference between the sexes for OP, SI, and HP was calculated using the Mann-Whitney U test (Table 3). Significant difference between sexes was only seen in the OP ($P = 0.029$) at 5% risk. The relations other than sex are graphically represented in Fig. 2. The HP had significant correlation with OP ($\rho = 0.418$) at 1% risk, and very small correlations with SI ($\rho = -0.160$) and AC ($\rho = 0.137$), also at 1% risk. The correlation coefficient between AC and OP was 0.470, AC and SI −0.299, and OP and SI −0.207, and these were significant at 1% risk. This showed that these factors were inseparably involved with each other. There was significant correlation between SI and SA ($\rho = 0.427$).

Relation between AC and OP

The statistical significance of difference between AC with OP was calculated using the Kruskal-Wallis test, and significant differences between them were found at 1% risk. Multiple comparisons based on the Kruskal-Wallis test for the AC showed that the teens class is different from any other class in OP (Table 4).[18] There were no significant differences between the twenties, thirties, and forties classes, and there were significant differences between these classes and the over-fifties classes below 5% risk. The fifties class had no significant difference with the over-sixties class. These results showed that there were three main groups: the teens class was apparently different from the other classes while the twenties, thirties, and forties classes formed one group, and the over-fifties classes formed the third group. The OP median was 0 (neutral) for the teens class, 1 (slight like) for the twenties and thirties classes, and 2 (like) for the over-forties classes (Table 4). Moreover, the average rank of the teens class was lower than the other age classes, those from the twenties to forties classes gradually increased, and those of the over-fifties classes were almost the same (Table 4). The results showed that the preference for dried shiitake mushrooms increased rapidly from the teens class to the twenties class, thereafter making slow progress from the twenties class to the fifties class, and finally reached a constant level at the fifties class.

The Japanese preferences for foods are affected by demographic factors. The first factor is age, the second factor region, and the third factor sex.[6–8] The preference greatly changes from the twenties to the forties: namely the preference for Japanese foods changes from dislike to like

Table 2. Correlation coefficients between age class, original preference, sample amounts, sensory intensity, and hedonic preference

	AC	OP	SA	SI	HP
AC	1.000	0.470**	0.000	−0.299**	0.137**
OP		1.000	0.000	−0.207**	0.418**
SA			1.000	0.427**	0.051
SI				1.000	−0.160**

The correlation coefficient was calculated using Spearman rank order correlation
AC, age class; OP, original preference; SA, sample amount; SI, sensory intensity; HP, hedonic preference
** Significant correlation at 1% risk

Table 3. Test of independence with male and female panelists for OP, SI, and HP

SA (mg/200 ml bottle)	*P* values	
	SI	HP
10	0.294	0.334
100	0.636	0.484
2000	0.529	0.415

Significant probability (*P*) was calculated by Mann-Whitney U test, and showed two-sided significant probability
OP showed significant difference at 5% risk ($P = 0.029$)

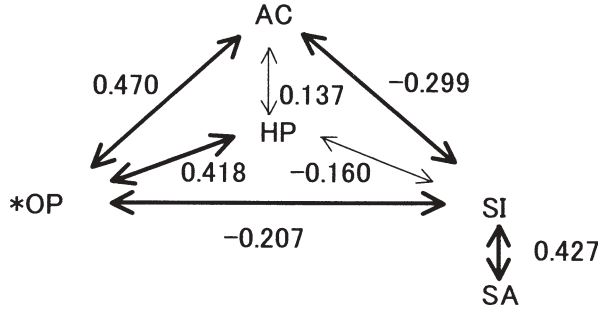

Fig. 2. Relations among factors. *AC*, age class; *HP*, hedonic preference; *OP*, original preference; *SI*, sensory intensity; *SA*, sample amount. The values show the Spearman rank order correlation coefficients between corresponding parameters at 1% risk, and *heavy lines* show an absolute value of significant correlation above 0.2, otherwise *thin lines* show less than 0.2 (Table 2). The *asterisk* indicates significant difference between males and females at 5% risk (Table 3)

Table 4. Statistical significance of the difference between AC and OP, and median

AC	Teens	Twenties	Thirties	Forties	Fifties	Over sixties
Teens		**	**	**	**	**
Twenties			NS	NS	**	**
Thirties				NS	**	**
Forties					*	**
Fifties						NS
Median	0	1	1	2	2	2
Average rank	83.85	130.40	140.18	150.64	190.37	193.63

The differences were calculated by Kruskal-Wallis test
NS, no significant difference
** Significant difference at 1% risk, * significant difference at 5% risk

between the twenties and thirties, and that for Western and heavy foods changes from like to dislike between the thirties and forties. With dried shiitake mushrooms looked upon as a Japanese food, the changes of those preferences of the over-twenties classes agreed with those reports. However, the dramatic change of the preference that occurred between the teens and twenties classes was earlier than that for other Japanese foods. The change of preference for coffee was observed between 14 and 16 years of age, and this was attributed to the effect of caffeine,[19] although such a substance has not been reported in dried shiitake mushrooms. The impressions of dried shiitake mushrooms for the teens class included "artificial foods" such as instant Chinese noodles or chemical condiment, while those for the over-twenties classes included "natural foods" such as boiled foods or Japanese soup. It is suspected that these changes in impression for dried shiitake mushrooms changed the OP from neutral to like.

Table 5. Correlation coefficients between AC and SI

	Whole	SA (mg/200-ml bottle)		
		10	100	2000
ρ	−0.299**	−0.389**	−0.246**	−0.346**

The values indicate Spearman rank order correlation coefficient
** Significant correlation at 1% risk

Table 6. Correlation coefficients between OP and SI

	Whole	SA (mg/200-ml bottle)		
		10	100	2000
ρ	−0.207**	−0.229**	−0.207**	−0.252**

The values indicate Spearman rank order correlation coefficient
** Significant correlation at 1% risk

Impact of sex

The statistical significance of the difference by the Mann-Whitney U test between male and female panelists for the OP is shown at 5% risk in Table 3. The median OP of male panelists was 1, and that of female panelists was 2; and average rank of male panelists was 134.08, and that of female panelists was 155.04, which showed that women like dried shiitake mushrooms more than men. Yamaguchi and Takahashi[7] reported that male subjects like protein-rich foods and female subjects like carbohydrate-rich foods. Protein-rich foods include boiled eel, grilled meat, etc., while carbohydrate-rich foods include seasoned steamed rice with vegetables and meat (takikomigohan in Japanese), pot-steamed hotchpotch (chawanmushi), etc., parts of which use dried shiitake mushrooms. Yamaguchi and Takahashi[7] also reported that OP was affected by frequency of eating. It is thought that female subjects eat foods that contain dried shiitake mushrooms more often than male subjects, and hence women grow to like the mushrooms more than men.

A number of studies have shown that female subjects were more sensitive to perception and discrimination of aroma than male subjects.[20–22] There was no significant difference by sex for SI in this study, although OP affected the SI. Higher OP values indicated a lower SI. These results showed that sex indirectly influenced the SI. It was thought that the difference attributable to sex was smaller than usual in this case.

Relation between AC and SI

The coefficient of rank correlation with Spearman between AC and SI is shown in Table 5. The correlation coefficient was −0.299 as a whole at 1% risk. In addition, the correlation coefficients for SAs of 10, 100, and 2000 mg were −0.389, −0.246, and −0.346 at 1% risk, respectively. The negative correlations between them showed that the olfactory function declined according to age. A threshold elevation for various odorants was more prominently observed in the elderly than in the young.[23–28] Recently it was reported that the age-related declines in olfaction were related to degeneration of parvalbumin immunoreactivity neurons and death of olfactory receptor neuron cells.[29,30] Therefore, the decline was suggested to be due to the normal physiological aging process.

Relation between OP and SI

The coefficient of rank correlation by Spearman between OP and SI was −0.207 as a whole at 1% risk (Table 6). In addition, those with SAs of 10, 100, and 2000 mg were −0.229, −0.207, and −0.252 at 1% risk, respectively. There existed negative correlations between them, and the more people like dried shiitake mushrooms, the weaker they feel the smell. Frank and van der Klaauw[31] reported that intensity of olfactory stimuli was generally lower for dislikers than likers. They studied 25 items, and the relations between sensory intensities and preference for 19 items showed such a correlation; however, that for 6 items, onion, cinnamon, etc., showed the opposite correlation. Moreover, most of the 6 items belonged to nonessential grocery items. Dried shiitake mushrooms are also regarded as a nonessential grocery food. Therefore, dried shiitake mushrooms might show negative correlation between OP and SI.

Relation between SI and SA

The SI was affected by the SA ($\rho = 0.427$ at 1% risk) (Table 2). The coefficients of correlation by Pearson between the 1,2,4-trithiolane, 1,2,4,6-tetrathiepane, and lenthionine amounts, and SA were 1.000, 0.991, and 0.988, respectively, and these were significant at 1% risk. It is known that a linear regression exists between SI and the odor concentration, as given by Weber-Fechner's law or Stevens' law, and the authors showed linear regression between them in a previous report.[16]

Table 7. Example of the distribution of the HP in likers

HP	SI											Total
	0	1	2	3	4	5	6	7	8	9	10	
3							2	2				4
2					2		4	1	6			13
1			1		7		10		4			22
0			5		5	1	2	1				14
−1					1		2		3	1		7
−2									1		1	2
−3											1	1
Median			0		1	0	1	2.5	1	−1		

Table 8. Highest median of HP and SI corresponding to the HP

OP	SI	HP
Extreme likers	8	2
Likers	7	2.5
Slight likers	7	1.5
Neutralists	7.5	1

Effects of OP and SI on HP

The coefficient of rank correlation by Spearman between HP and OP was 0.418 and significant at 1% risk (Table 2). On the other hand, those between SI and HP, and AC and HP were less than 0.2, namely there were no correlations (Table 2), which showed that HP was only affected by OP. However, it was known that the aromatic intensity was one of the important factors for food quality; namely, the HP scores are low when the concentration of fragrance is strong or weak.[31] Therefore, the low correlation coefficient between SI and HP was attributed to the Spearman test, which was premised on asymptotic theory. Moreover, it was thought that dislikers showed a negative correlation between SI and HP.

To clarify the relations for HP, OP, and SI, the panelists were classified by OP, extreme liker, liker, slight liker, neutralist, and disliker, because the number of dislikers was too small to subdivide any further. An example of HP distribution with likers is shown in Table 7. The distribution suggested that there was an optimal value. For estimating the sensory intensities that caused the highest HP for likers and neutralists, the median HP was calculated at each SI, and the highest HP and SI corresponding to that are shown in Table 8. The HP ranged from 1 to 2.5, and the SI ranged from 7 to 8, which showed that there was an optimal SI. Moreover, the optimal SI was almost constant regardless of OP, and between a slightly strong and strong smell. Whereas for dislikers, the distribution suggested that there was a negative correlation between HP and SI. The coefficient of rank correlation by Spearman between them was −0.533 and significant at 5% risk, which showed that the HP for dislikers decreased according to increasing SI. From these results, it was recognized that the responses for the smell differed according to whether the smell was considered pleasant or unpleasant. Different regions of the human brain are activated by pleasant and unpleasant odors,[32,33] which might be one reason for the different response.

Optimal amount of dried shiitake mushroom for HP

The HP was affected by OP and SI, and the SI was affected by AC and SA. Therefore, the optimal amount of dried shiitake mushroom for likers and neutralists was inferred to comprehend the relations, using the equation described by Stevens' law. For purposes of the estimation, AC were grouped into three classes: the teens class, the twenties to forties class, and the over-fifties class (Table 4). The optimal amount increased according to rising OP and AC in general, and the value ranged widely, from 100 to 1470 mg per 200-ml bottle (Table 9). The increase of the optimal amount according to aging was due to the compensation for the decrease of the SI (Table 5). It was thought that the increase of the optimal amount along with OP was attributable to elevation of desire. On the other hand, dislikers did not accept dried shiitake mushroom, because there was a negative correlation between HP and SI. To allow dislikers to accept dried shiitake mushrooms, little or almost no odor material is needed.

However, consumers have no chance to select dried shiitake mushrooms adapted to their individual preferences, because the mushrooms are mostly evaluated in markets by their shape and not by other qualities. It is necessary to produce different kinds of dried shiitake mushrooms in which the odor intensities are different, including a type with little odor, and classify them according to odor concentration, to increase their consumption.

Acknowledgments This work was supported in part by a Grant-in-Aid (Integrated Research Program for Effective Use of Biological Activities to Create New Demand) from the Research Council, Ministry of Agriculture, Forestry, and Fisheries of Japan, and a Research Grant of the Forestry and Forest Products Research Institute (#200403). The authors are grateful to the staff members and students of Yokosuka Civic Nagai Elementary School, Miura Civic Misaki Junior High School, Kanagawa Prefectural Ohgusu Senior High School, and Yokohama National University, and the staff members of the Forestry and Forest Products Research Institute of Japan, and retired employees in Fukuoka Prefecture for cooperating with the questionnaires. In addition, we express special thanks to Ms. Mizuho Narahashi, Mr. Takahiko Masuda, Mr. Kimio Takahashi, Prof. Yukira Mochida, Dr. Shuichi Ishihara, Mr. Mitsushi Hasuo, and Ms. Michiko Hasuo for arranging the questionnaires.

Table 9. Inferred amount of dried shiitake mushroom for the suitable SI

AC	OP			
	Neutralists	Slight likers	Likers	Extreme likers
Teens	NS	100*	[a]	[a]
Twenties to forties	330**	350**	268**	758*
Over fifties	[a]	[a]	553**	1470**

The amount was inferred from SI using the regression equation of SI and amount of dried shiitake mushroom, which was calculated using Stevens' law. The amounts are expressed as mg/200-ml bottle

** Significant at 1% risk, * significant at 5% risk

[a] The number of panelists was less than 3

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