

MASSACHUSETTS  
AGRICULTURAL EXPERIMENT STATION  
MUSHROOMS FOR  
FOOD AND FLAVOR

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**Mushrooms**  
**For Food and Flavor**

By William B. Esselen, Jr., and Carl R. Fellers

Laboratory studies prove that mushrooms, besides serving as a flavor or garnish for other foods, are a nutritious food in themselves.

MASSACHUSETTS STATE COLLEGE  
AMHERST, MASS.

# MUSHROOMS — FOR FOOD AND FLAVOR

By William B. Esselen, Jr., Assistant Research Professor and Carl R. Fellers,  
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This bulletin represents a summary of work carried on in this laboratory during the past five years for the purpose of determining the food value of the commercially grown mushroom, *Agaricus campestris*. Up to the time this investigation was initiated but little information was available on the nutritive value of this food. The results obtained show that when we eat mushrooms for their pleasing flavor and as a garnish for other dishes, we are at the same time helping ourselves to a nutritious food, particularly rich in the B vitamins.

## Mushroom Growing and Use

For centuries mushrooms have been highly esteemed as a food. The Pharaohs of Egypt knew and prized the mushroom and believed that it grew up over night, magically. In fact, during the reign of the Ceasars in Rome there was a law concerning the grading and selling of mushrooms — a forerunner of our present food laws. Mushrooms were thought to provide warriors with unusual strength in battle. The Romans called them "food of the gods" and they were usually served only on festive occasions. The fine qualities of mushrooms were eulogized by the poet Horace before the Christian era.

Up to the 17th century the use of mushrooms was confined to the wild types, found growing in meadows and pastures. During the reign of Louis XIV mushroom culture was introduced in France. Parisian market gardeners made every effort to learn the secrets of successful mushroom culture. In 1749 caves and cellars were employed as locations for mushroom beds and the results showed such an improvement over former methods that a new impetus was given to mushroom culture. Thus a large mushroom industry was developed in France that amounted to as much as \$2,000,000 annually. Dried and canned mushrooms were imported into this country in large amounts from about 1850 up to World War I.

A little over fifty years ago the art of mushroom culture was introduced to American growers and since then marked improvements have been made over former methods. About 1918 the development of commercial methods for the production of pure culture mushroom spawn did much to stimulate commercial mushroom growing.

In the United States mushrooms are usually grown commercially in especially constructed growing houses or buildings that are long and windowless and protected against severe temperature changes. The mushrooms are grown under conditions of controlled temperature and humidity in beds of rich humus. The humus of the beds is inoculated with pure cultures of the mushroom spawn. It takes about six weeks from the time the beds are inoculated before the mushrooms show up in definite "breaks". The mushrooms are usually gathered daily when they are of medium size and before the veil (the thin membrane under the cap stretching from the edge of the cap to the stem covering the gills) breaks.

After being picked the mushrooms are sorted and graded in packing rooms, according to Rettew, Gahm and Divine (20). They are usually sorted into four grades and may be graded as follows:

<sup>1</sup>Acknowledgement is due the Cultivated Mushroom Institute of America, New York, N. Y., for their interest and assistance in the preparation of this bulletin; and to Mr. G. R. Rettew of the Chester County Mushroom Laboratories, West Chester, Pa., for permission to use pictures shown in Plates 3 and 6.

*First Grade or "Specials"* — good quality mushrooms of the larger size. They must be tight (the veil not broken) and free from blemishes.

*Second Grade or "Fancies"* — medium sized mushrooms. Must be tight and free from blemishes.

*Third Grade or "Buttons"* — smaller mushrooms that are tight and free from blemishes.

*Fourth Grade or "Spots and Opens"* — off-quality or second-rate mushrooms including open, spotted, or blemished mushrooms of all sizes.

Mushrooms should be brought to the consumer as fresh as possible, preferably the same day or the day after they are picked. Deterioration in fresh mushrooms can be retarded by holding them under dry storage conditions between 36° and 40°F.

During the past 15 years the American mushroom industry has expanded rapidly until it is now one of the important food industries. In 1940 alone, over 40 million pounds of fresh mushrooms were produced in the United States. Pennsylvania produced approximately 55 percent of the total crop, while the remainder was grown in areas near Boston, Chicago, Cleveland, Kansas City, San Francisco, and along the Hudson River. The mushroom industry is also an important food industry in Canada. In addition to the fresh market, large quantities of mushrooms are canned as such or in soups. The canned pack of mushrooms in 1943 amounted to 400,000 cases.

#### Nutritive Value of Mushrooms

Until recently mushrooms were eaten almost entirely for their condimental value. The incorporation of mushrooms into gravies, sauces, soups, and other dishes added zest and flavor. However, the results of recent investigations would tend to place mushrooms in the average American diet not only on the basis of their already recognized flavor-enhancing properties but also because of certain definite food values the mushroom was found to possess.

A survey of the literature on the composition and nutritive properties of mushrooms presents a rather confused picture. This is due in part to the fact that many different types of mushrooms are reported under a common heading with little or no regard for variety. The nutritive properties and composition of different varieties of mushrooms do vary, often to a marked extent. The investigations carried out at this laboratory were concerned entirely with the commercially cultivated mushroom, *Agaricus campestris*, and not with any of the "wild" or foreign mushrooms.

#### Proximate Composition

The composition of fresh mushrooms is similar to that of many fresh vegetables and fruits as the following proximate analysis of *Agaricus campestris*, given by Anderson and Fellers (1), indicates:

Water.....	89.50 percent
Protein (N x 6.25).....	3.94
Fat (ether extract).....	0.19
Extract matter.....	4.01
Fiber.....	1.09
Ash.....	1.26

An analysis of the ash of fresh mushrooms gave the following results:

Calcium.....	0.0024 percent
Phosphorus.....	0.15
Potassium.....	0.50
Total iron.....	19.50 p.p.m.
Available iron.....	5.95 p.p.m.
Copper.....	1.35 p.p.m.

### Protein

The protein present in mushrooms has long been a subject of much discussion. The controversy has ranged from the extreme of calling mushrooms the "vegetable beefsteak" to the opposite extreme when Chatfield and Adams (4) assigned a value of zero for the percentage of protein in mushrooms.

Saltet (21) employed human beings to test the digestibility of mushroom nitrogen and reported that 69 percent of the total nitrogen of *Agaricus campestris* existed in the form of protein. He concluded further that 50 percent of the total nitrogen was in the form of a digestible protein. Mendel (14) and Konig (12) indicated that the protein content of mushrooms was approximately 5 percent, and expressed the opinion that mushrooms would be a good source of protein.

Skinner, Peterson and Steenbock (23) investigated the digestibility of the protein of *Agaricus campestris* with albino rats and found it to be 71 percent, in fairly close agreement with the findings of Saltet (21). However, these data were not in agreement with those of Morner (16) who reported that only 50 percent of the total nitrogen of mushrooms was capable of being digested in vitro.

Recently Fitzpatrick, Esselen and Weir (7) have reported the results of an extensive investigation on the composition and nutritive value of mushroom (*Agaricus campestris*) protein. Several rat-feeding experiments were carried out according to the paired-feeding method of Mitchell and Beadles (15). Assigning an arbitrary value of 100 to purified casein, the relative quality of mushroom protein was 32.6 when they were fed at an 8 percent protein level. When the level of protein was increased to 15 percent, the relative quality of mushroom protein increased to 56.6 percent. The data indicated that the mushroom protein contained all of the amino acids essential for the rat. The fact that the rats on the mushroom diets did not gain as much weight as those on the control diet indicated that the essential amino acids, although present, were probably in low concentrations in the case of certain individual acids. As is discussed later the tryptophane content of mushroom protein was found to be particularly low.

Studies on the mushroom protein itself showed that total nitrogen content of *Agaricus campestris* was approximately 0.5 percent of which 63 percent was in the form of protein. Purified mushroom protein was found to have a nitrogen content of 11.79 percent.

By means of qualitative chemical tests the mushroom protein was found to contain the following essential amino acids: phenylalanine, histidine, leucine, lysine, arginine, tryptophane, and threonine. The essential amino acids which failed to give positive tests were: valine, isoleucine, and methionine. However, that these three essential amino acids were also present was borne out by the animal feeding trials.

The microbiological technique was employed in making a quantitative determination of certain of the amino acids in mushrooms. The dried mushrooms were hydrolyzed, prior to assay, in a manner similar to that described by Schweigert, McIntire, Elvehjem, and Strong (22). The microbiological method of

Hutchings and Peterson (9) was followed, using *Lactobacillus arabinosus* 17-5 as the test organism. The amino acid content of mushrooms on a fresh weight basis as determined above was found to be as follows:

Amino acid	Mg. per 100 grams fresh weight basis
l-arginine.....	203.17
dl-isoleucine.....	458.85
l-leucine.....	242.02
dl-methionine.....	144.37
l-tryptophane.....	5.07
dl-valine.....	326.02

Although the results of the animal feeding tests indicate the presence of all of the essential amino acids in mushroom protein, taken by themselves they may be open to question. However, the chemical and microbiological tests bear out the fact that these amino acids are present, even though in small amounts in some cases. Positive chemical tests were not obtained for valine, isoleucine, and methionine but their presence was demonstrated by the microbiological tests.

\*It was concluded that fresh mushrooms (*Agaricus campestris*) contain approximately 2.67 percent of protein. While they are not comparable with such foods as meat and fish as a source of protein, they do compare favorably with many fresh vegetables in this respect.

### Carbohydrate

But little information has been found on the carbohydrate content of mushrooms (*Agaricus campestris*). Inagaki (10) found mannitol present in wild mushrooms (*Agaricus campestris*) in concentrations of 0.93 percent of the dry weight of the cap and 0.17 percent of the stipe. Nickerson and Rettew (17) isolated and identified mannitol from the same variety. They reported an average of 5.5 percent of the dry weight of the immature button stage and 9.9 percent of the dry weight of the mature open stage recovered as mannitol. Other carbohydrates and poly-alcohols such as trehalose, glucose, glycogen, sorbitol, pentoses, and cellulose have been reported present in other varieties.

McConnell and Esselen (13) have reported on the carbohydrate content of mushrooms (*Agaricus campestris*) grown in Massachusetts by a commercial grower. Good quality, large, fresh mushrooms in the closed stage were selected, sliced into quarter-inch pieces, and dried. The dried product was ground in a Wiley mill to pass through a 60-mesh screen. The A. O. A. C. (2) method for analysis of sugars in plants was followed. Qualitative tests were made for the presence of the various carbohydrates. By means of these tests many carbohydrates were found to be absent in the mushroom. Quantitative tests were then made for those carbohydrates whose presence might have accounted for the positive qualitative tests. The results are shown in table 1.

The reported mannitol content is, in general, in agreement with the amount found in this same variety by Nickerson and Rettew (17) but is much higher than that reported by Inagaki (10) for wild mushrooms. The carbohydrates present in greatest quantities were mannitol, hemicellulose, glycogen, and reducing sugars, which together accounted for 2.73 percent of the weight of the fresh mushrooms.

TABLE 1.—CARBOHYDRATES AND POLY-ALCOHOLS IN MUSHROOMS  
(*AGARICUS CAMPESTRIS*).

Substance	Fresh Weight Basis* Percent	Moisture-free Basis Percent
Mannitol.....	0.95	8.56
Reducing sugars (as dextrose).....	0.28	2.48
Pentoses, methyl pentoses, hexuronic acids.....	0.04	0.32
Glycogen.....	0.59	5.34
Crude hemicellulose.....	0.91	8.18
Total.....	2.77	24.88

\*88.90 percent water.

### Vitamins

Until quite recently little investigational work has been reported on the vitamin content of mushrooms. Orton, McCollum and Simmonds (18) found *Agaricus campestris* to be a good source of water soluble vitamin B. Hara (8) and Quackenbush, Peterson, and Steenbock (19) also reported mushrooms to be a good source of the B vitamins.

Cheldelin and Williams (5) reported the B vitamin content of fresh mushrooms purchased on the market, as gamma per gram on a fresh weight basis, to be thiamin, 12.5; riboflavin, 3.3; nicotinic acid, 69; pantothenic acid, 17; pyridoxin, 0.45; biotin, 0.16; inositol, 170; and folic acid, 0.98.

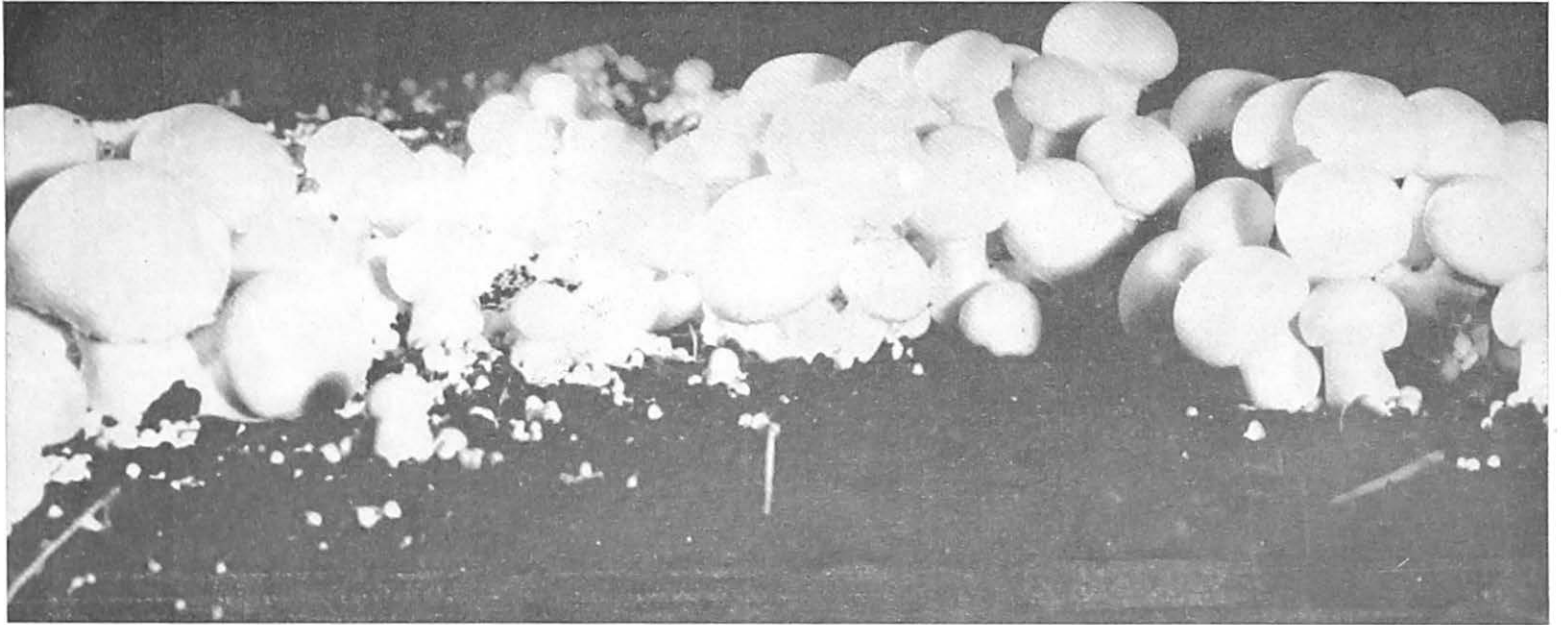
The vitamin content of fresh, commercially grown *Agaricus campestris* has been determined in this laboratory and reported by Anderson and Fellers (1), Brunell, Esselen and Griffiths (3), and Filios and Esselen (6) as shown in table 2.

It is evident that cultivated mushrooms are one of the best plant sources of several members of the vitamin B complex. They contain an appreciable amount of thiamin and are an excellent source of riboflavin and nicotinic acid as well as a good source of pantothenic acid.

TABLE 2.—VITAMIN CONTENT OF FRESH MUSHROOMS.

Vitamin	Mg. per 100 g. Fresh Weight Basis
Vitamin A.....	None*
Vitamin D.....	None*
Vitamin E.....	None
Vitamin K.....	++
Ascorbic Acid.....	8.60
Thiamin.....	0.12
Riboflavin.....	0.52
Nicotinic Acid.....	5.85
Pantothenic Acid.....	2.38
Biotin.....	0.018

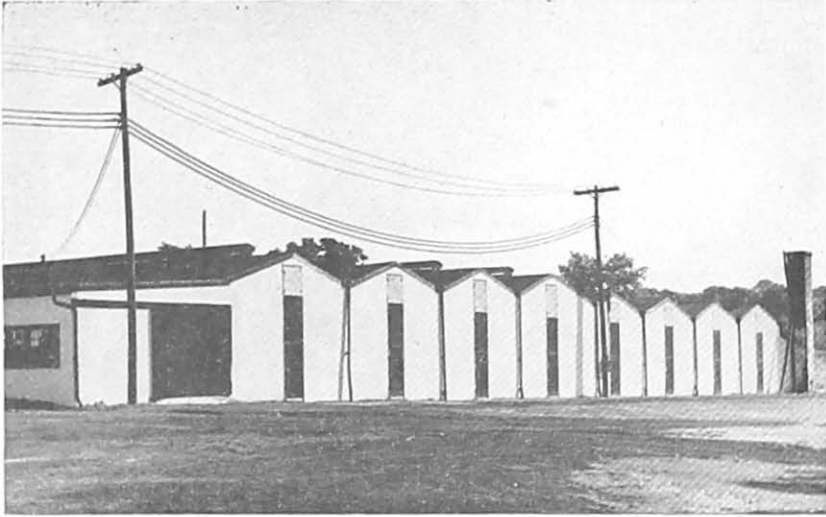
\*International units.



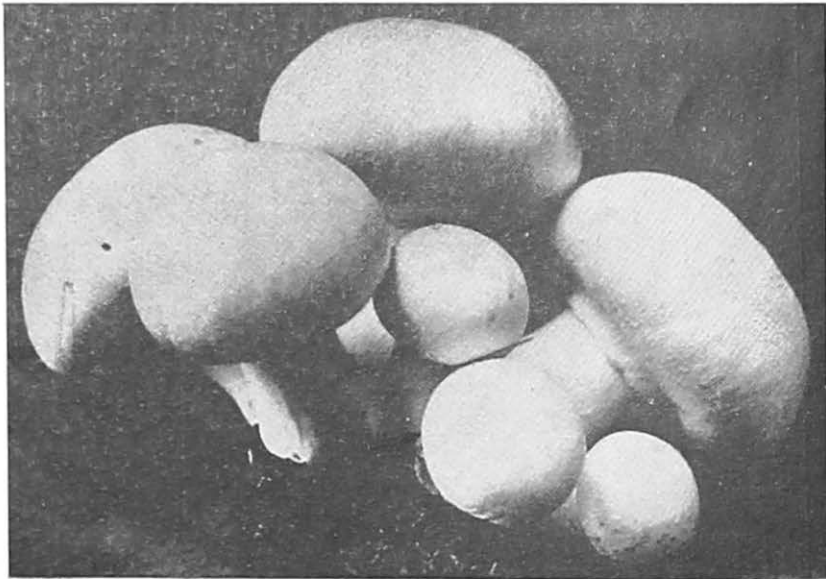
**Plate 1.**

**A "break" or "flush" of cultivated mushrooms in bed of specially prepared soil in dark growing house. It takes about six weeks from the time the beds are inoculated for the mushrooms to show up in definite "breaks".**

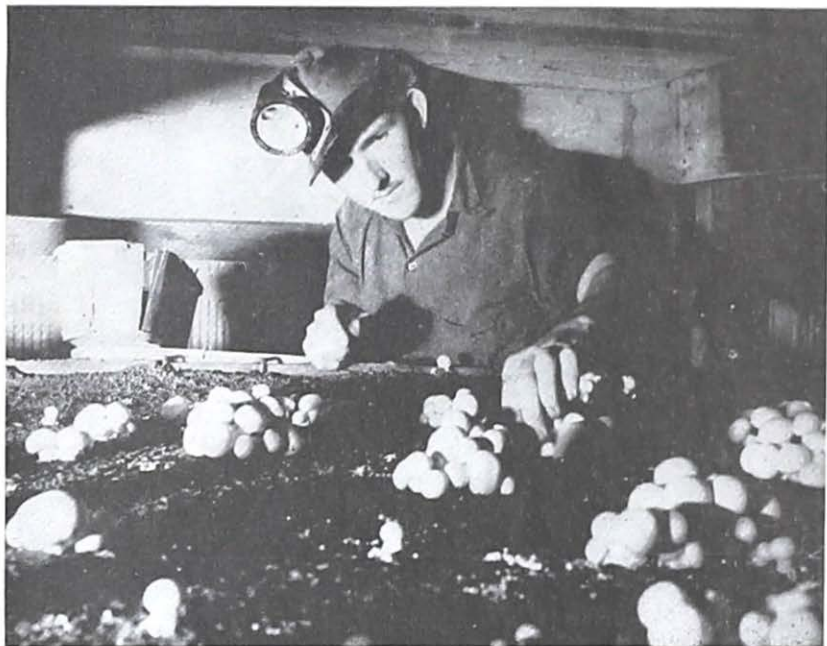




**Plate 2**  
Specially constructed growing houses in which cultivated mushrooms are grown scientifically under controlled temperature conditions.



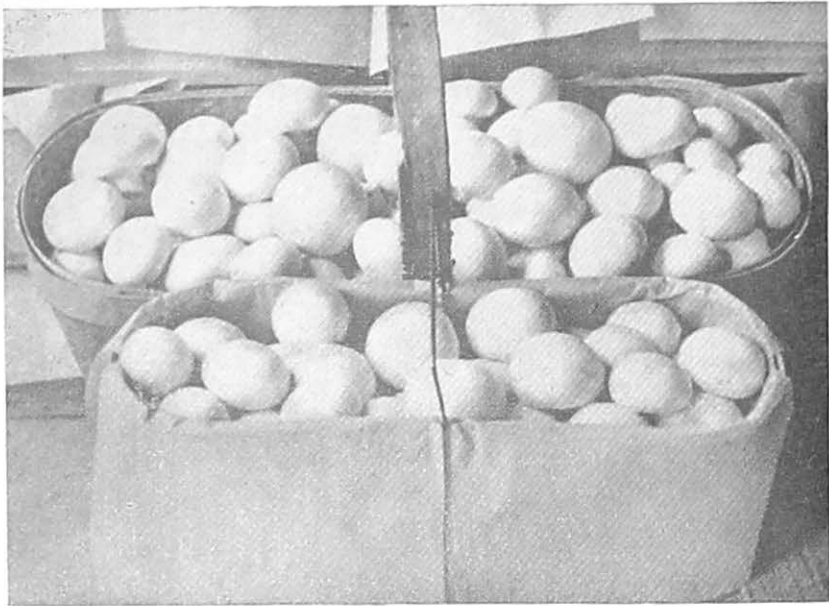
**Plate 3**  
A cluster of cultivated mushrooms.



**Plate 4.**  
**Picking Mushrooms.**  
Mushrooms grow in the dark; note miner's lamp in the cap of the picker.



**Plate 5.**  
**Packing fresh mushrooms for market.**  
The mushrooms are placed in the basket by hand as they are sorted.



**Plate 6.**  
**Basket of fresh mushrooms ready for market.**



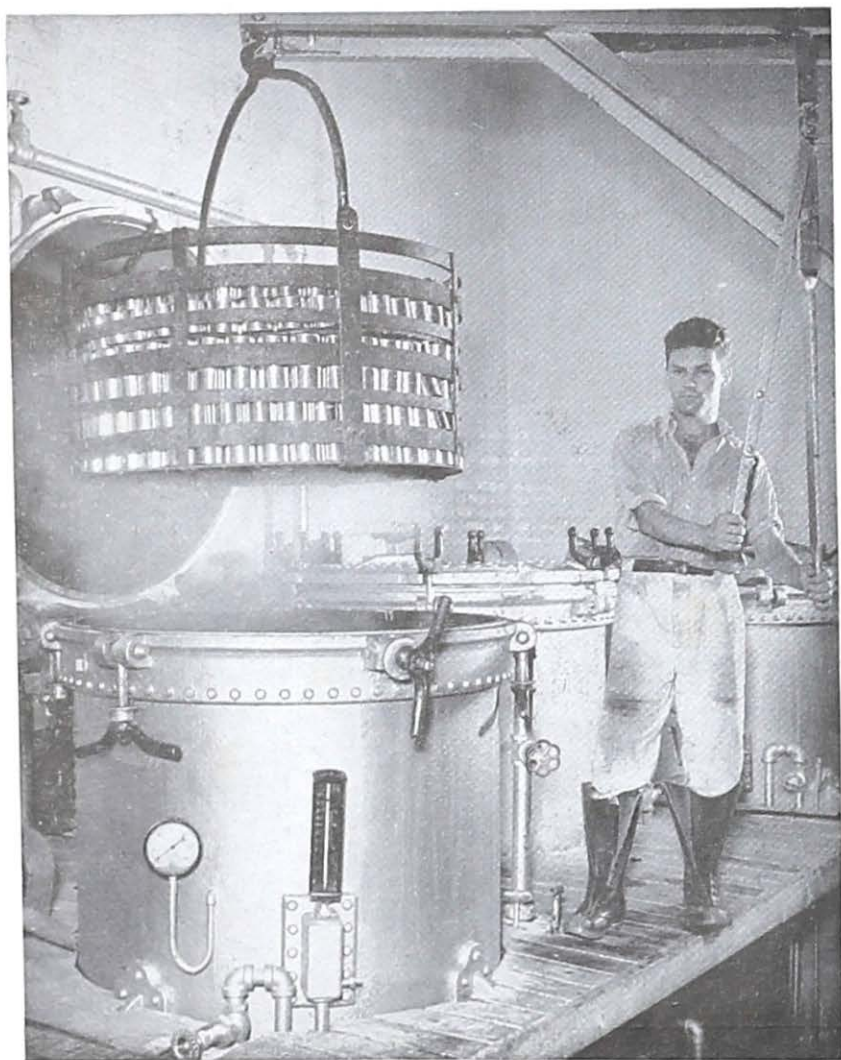
**Plate 7.**  
**Mushrooms are thoroughly washed before they are canned.**



**Plate 8.**

Small mushrooms are canned whole as Buttons. Girls fill and weigh the cans before they are sealed.

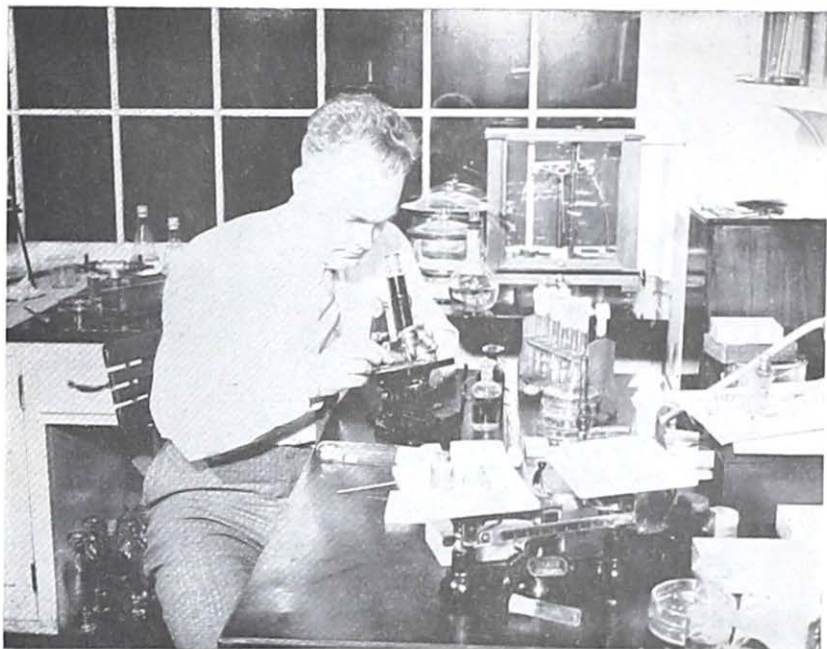
Large mushrooms are canned as Sliced, and open mushrooms as Stems and Pieces.



**Plate 9.**

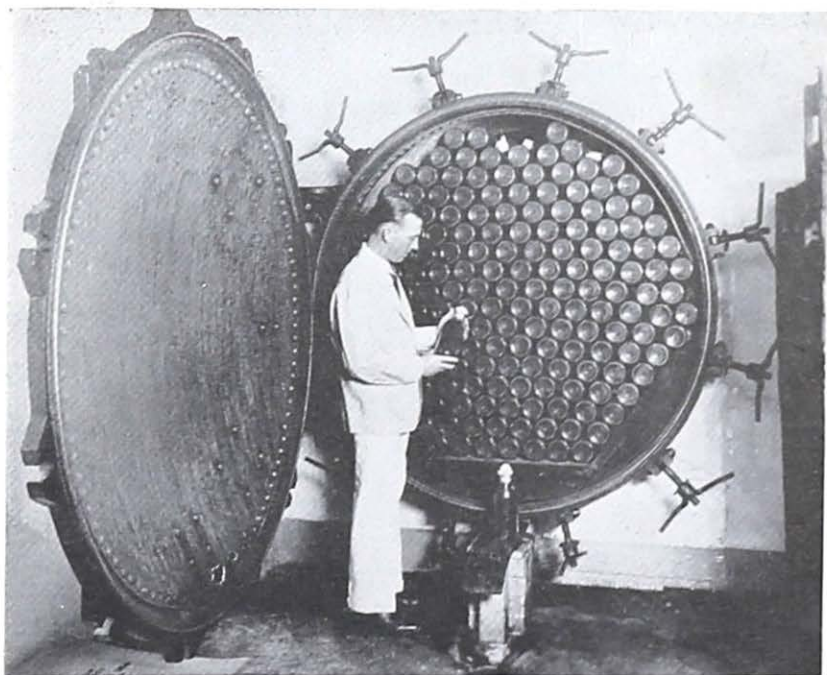
**The canned mushrooms are processed or "sterilized" in large retorts at 10 or 15 pounds steam pressure.**





**Plate 10.**

Mushrooms begin their lives in the laboratory, where trained scientists select the choicest mushrooms and place sections in sterile glass tubes. These tubes, plugged with cotton, are placed in an incubator and held at constant temperature and humidity for 72 hours. During this time spores drop from the gills of the mushroom and produce a spore print within the glass tube.



**Plate 11.**

Jars of nutrient medium for the pure culture of mushroom spawn are sterilized in large steam retorts.



**Plate 12.**

**Technician making transfer of spawn from master flask to large culture bottles. The spawn culture is inoculated into growing beds where it spreads or "runs" through the beds until in two or three weeks it appears as fine white threads on the surface.**

### Effect of Cooking on Vitamin Content of Fresh Mushrooms

Filios and Esselen (6) found that in general the B vitamins are well retained when fresh mushrooms are cooked. Fresh mushrooms were cooked by five different methods: (1) boiled whole, (2) boiled sliced, (3) broiled whole, (4) broiled sliced, and (5) sauteed. The results are summarized in table 3. The vitamin content of the cooking liquor, as well as that of the cooked solids was determined, in order to calculate the total vitamin retention.

There was little loss of riboflavin in most cases. The broiled sliced mushrooms suffered most, retaining but 65.8 percent of the riboflavin. The nicotinic acid losses were in approximately the same range, with 77.6 to 91.3 percent retained during cooking. The percentage retention of pantothenic acid ranged from 74.6 to 100 percent. The biotin values obtained were somewhat lower, ranging from 42.2 to 62.8 percent retention. The relatively low retention of biotin is probably apparent rather than actual, owing to the difficulty in extracting biotin from the samples for assay. It was concluded that in general, riboflavin, nicotinic acid, pantothenic acid, and biotin are well retained when fresh mushrooms are cooked by various methods.

TABLE 3.—EFFECT OF COOKING METHODS ON RETENTION OF B VITAMINS IN FRESH MUSHROOMS.

Cooking Method	Retention, Percent			
	Riboflavin	Nicotinic Acid	Pantothenic Acid	Biotin
Boiled whole.....	100.0	89.6	100.0	62.8
Boiled sliced.....	84.5	90.3	89.4	42.2
Broiled whole.....	89.5	90.2	86.4	55.5
Broiled sliced.....	65.8	91.3	74.6	41.8
Sauteed.....	94.3	77.6	76.6	43.2

### Effect of Canning on Vitamin Content of Mushrooms

Investigations on the stability of B vitamins in mushrooms during canning and storage and on the B vitamin content of commercially canned mushrooms have been reported by Filios and Esselen (6).

Fresh mushrooms were secured from a nearby grower and experimental packs were prepared in the laboratory to study the vitamin stability during canning and storage. The riboflavin, nicotinic acid, pantothenic acid, and biotin content of the mushrooms was determined by microbiological methods. Determinations were made on the fresh mushroom, the blanched mushroom, and the canned product immediately after canning and at intervals of 2, 6, and 12 months during storage at room temperature (70°-80°F.)

The mushrooms were washed and trimmed, blanched for seven minutes in boiling water, packed into No. 2 size (307 x 409) tin cans with a standardized fill-in weight, and brined. The cans were then sealed and processed in a retort for 25 minutes at 240°F. (116°C.). A summary of the data is presented in table 4. There was a small loss of riboflavin, nicotinic acid, pantothenic acid, and biotin during the canning process and a further loss during storage for twelve months. Despite these losses canned mushrooms are excellent sources of riboflavin, nicotinic acid, pantothenic acid, and biotin, even after storage for one year.



TABLE 4.—RETENTION OF B VITAMINS IN CANNED MUSHROOMS DURING CANNING AND STORAGE AT ROOM TEMPERATURE.

Storage Time Months	Riboflavin		Nicotinic Acid		Pantothenic Acid		Biotin	
	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent
Fresh...	0.348	...	3.65	...	1.214	...	0.0061	....
Blanched.	.342	98.4	2.78	76.2	0.99	80.0	.0068	111.5
7.....	.318	91.5	2.66	73.0	0.58	46.8	.0050	82.0
2.....	.297	85.3	2.96	78.4	1.06	85.3	.0051	83.6
6.....	.240	69.0	2.48	68.0	0.87	70.1	.0048	78.7
12.....	.225	64.7	2.11	57.8	0.75	60.5	.0048	78.7

TABLE 5.—THE B VITAMIN CONTENT OF COMMERCIALY CANNED MUSHROOMS.

Type and Sample Number	Riboflavin Mg./100 g.*	Nicotinic Acid Mg./100 g.*	Calcium Pantothenate Mg./100 g.*	Biotin Mg./100 g.*
<b>Buttons</b>				
1.....	0.229	1.84	0.917	0.0067
4.....	.334	2.61	1.042	.0058
7.....	.352	2.69	0.827	.0070
10.....	.256	1.50	0.867	0.043
13.....	.183	2.08	1.179	.0062
16.....	.318	2.16	1.258	.0082
Average.....	.278	2.04	1.015	.0064
<b>Sliced</b>				
2.....	.263	1.96	0.914	.0041
5.....	.313	2.53	1.000	.0068
8.....	.279	1.63	0.853	.0077
11.....	.231	1.97	0.913	.0086
14.....	.191	1.56	0.877	.0071
17.....	.319	2.22	1.126	.0100
Average.....	.266	1.98	0.947	.0074
<b>Stems and Pieces</b>				
3.....	.227	1.69	0.697	.0033
6.....	.221	1.79	0.506	.0046
9.....	.213	1.00	0.450	.0076
12.....	.210	1.57	0.716	.0077
15.....	.160	0.98	0.312	.0063
18.....	.181	1.30	0.510	.0062
Average.....	.202	1.39	0.532	.0060

\*Total can contents.

In order to obtain information on commercial canned mushrooms, samples were obtained from six different commercial canners. Each canner supplied samples of (1) button mushrooms, (2) sliced mushrooms, and (3) stems and pieces in 5.5 ounce cans. Three to six months after they were canned the mushrooms were analyzed for riboflavin, nicotinic acid, pantothenic acid, and biotin. For each vitamin determination a composite sample from six cans was taken. The results obtained, as shown in table 5, confirm the laboratory tests in showing that commercially canned mushrooms are excellent sources of the four vitamins under consideration.

The canned button and sliced mushrooms were a better source of the B vitamins studied than the canned mushroom stems and pieces. It is of interest that the vitamin content of commercially canned mushrooms obtained from different canners was more uniform than the vitamin content of many other kinds of canned foods as reported by Thompson, Cunningham and Snell (24) and Ives, Wagner, Elvehjem and Strong (11). This is undoubtedly attributable, at least in part, to the uniform cultural conditions employed in raising mushrooms.

#### Effect of Drying and Freezing on Vitamin Content of Mushrooms

In an investigation on the dehydration and freezing of mushrooms Brunell, Esselen, and Griffiths (3) obtained data on the stability of thiamin, riboflavin, and nicotinic acid during these operations. Their data are summarized in table 6.

During steam blanching and dehydration, the loss of thiamin was approximately 18 percent and that of nicotinic acid about 12 percent. It is probable that most of these losses occurred in the blanching process. There was little or no loss of riboflavin. All three of these vitamins were quite stable during storage for five months at room temperature (75°-80°F.).

With frozen mushrooms there was a slight loss of riboflavin and some loss of thiamin during blanching prior to freezing, but all of these vitamins were quite stable in the frozen product.

TABLE 6.—EFFECT OF DEHYDRATION AND FREEZING ON THE STABILITY OF THIAMIN, RIBOFLAVIN, AND NICOTINIC ACID IN MUSHROOMS.

Storage Time Months	Thiamin		Riboflavin		Nicotinic Acid	
	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent	Mg. per 100 g.	Retention Percent
<b>Fresh:</b>						
Moist basis.....	0.116	...	0.540	...	6.20	...
Dry basis.....	1.066	...	4.960	...	56.99	...
<b>Dehydrated (dry basis):</b>						
0.....	.882	82.7	4.900	98.7	50.10	87.9
1.....	.880	82.6	4.820	97.2	50.60	88.9
2.....	.875	82.1	5.000	100.8	49.20	86.3
3.....	.883	82.8	4.860	98.0	49.70	87.3
4.....	.878	82.4	4.930	99.4	....	...
5.....	.875	82.1	4.800	96.8	....	...
<b>Frozen (moist basis):</b>						
0.....	.100	86.2	.520	96.3	5.65	91.2
1.....	.100	86.2	.517	95.6	5.63	90.8
2.....	.097	83.7	.522	96.7	5.66	91.3
3.....	.096	82.7	.521	96.5	5.63	90.8

### Summary and Conclusions

Recent work on the nutritive value of cultivated mushrooms (*Agaricus campestris*) provides evidence that would tend to place them in the average American diet not only on the basis of their already recognized flavor-enhancing properties but also because of certain definite food values the mushroom has been found to possess.

1. The mineral content of mushrooms provides an additional source of iron and copper.

2. Fresh mushrooms contain approximately 2.67 percent of protein and all of the essential amino acids, at least in small amounts. While not comparable with such foods as meat and fish as a source of protein, mushrooms do compare favorably with many fresh vegetables in protein content.

3. Mushrooms contain small amounts of carbohydrates and carbohydrate-like substances.

4. Mushrooms were found to be an excellent plant source of riboflavin and nicotinic acid and a good source of pantothenic acid. They also contain appreciable amounts of thiamin and biotin. These vitamins are well retained during cooking, and in canned, dehydrated, and frozen mushrooms.

5. Commercially canned mushrooms as purchased by the consumer were found to be excellent sources of certain of the B vitamins. The content of these vitamins was quite uniform in commercially canned mushrooms packaged by different canners.

6. Although mushrooms will probably always be eaten for their innate flavor and taste appeal, they do possess definite food values and are not merely a fancy source of good flavor with no nutritional merit.

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