FACTORS AFFECTING ONION PUNGENCY[1]

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INTRODUCTION

Both mild and pungent onions are demanded for food, the particular use being made of them determining the type required. When onions are used in salads, for seasoning, or as a cooked vegetable, bulbs of relative mildness are usually preferred. On the other hand, a market for highly pungent varieties is created by the manufacturers of such products as sauces, canned soups and extracts, sold in the form of onion powder and onion salt.

The factors influencing the pungency of onions should be of interest to producers and buyers, especially those who use large quantities of this vegetable for manufacturing various food products. Heretofore, no such study has been carried out, mainly because no method was available of measuring small differences in pungency with any degree of accuracy. By means of tasting tests, it is possible to decide whether one particular bulb is stronger than another one, but such a procedure hardly lends itself to an accurate classification of a large number of varieties.

The particular constituent to which the onion (*Allium cepa* L.) owes its pungency was first identified by Lemmler [2] as a volatile oil, known chemically as allyl-propyl-disulfide. Based on these findings, a method was developed by Platenius [3] for determining quantitatively the content of volatile oil in the bulbs. After prolonged hydrolysis, the onion oil is distilled and the total sulfur content is determined in the distillate. The dependability of this method has frequently been checked against tasting tests, and in every instance the differences found noticeable by tasting tests corresponded to differences in the volatile-sulfur content of the bulbs. This fact cannot be considered as conclusive proof of the reliability of the method; still, it is the only confirmation of its value available at the present time.

Preliminary experiments carried out by the writers established the fact that onions differ in pungency not only as a result of genetic factors but also because of soil and other ecological conditions. It was found, for instance, that Italian Red onions imported from Italy were consistently milder than bulbs of the same variety grown in New York. In an earlier publication,[4] the writers also showed that the pungency of onions increases with maturity until the tops begin to fall over. This makes it necessary to compare the pungency of different varieties when the bulbs have reached the same degree of maturity.

[1] Received for publication June 29, 1940. Paper No. 217, Department of Vegetable Crops, Cornell University.

[2] LEMMLER, F. W. DAS ÄTHERISCHE ÖL DER KÜCHENZWIEBEL (ALLIUM CEPA L.). Arch. der Pharm. 230: 443–448. 1892.

[3] PLATENIUS, HANS. A METHOD FOR ESTIMATING THE VOLATILE SULPHUR CONTENT AND PUNGENCY OF ONIONS. Jour. Agr. Res. 51: 847–853, illus. 1935.

[4] PLATENIUS, HANS, and KNOTT, J. E. THE PUNGENCY OF THE ONION BULB AS INFLUENCED BY THE STAGE OF DEVELOPMENT OF THE PLANT. Amer. Soc. Hort. Sci. Proc. 33: 481–483, illus. 1936.

The present study was undertaken to classify the most important commercial varieties with respect to pungency and to ascertain to what extent factors such as soil conditions, temperature, moisture supply, and storage influence the pungency of any one variety.

RELATIVE PUNGENCY OF DIFFERENT ONION VARIETIES

In the study carried out in 1936 and 1937 a comparison was made of the relative pungency of 16 varieties of onions, including most of the commercially important types. As is commonly known, certain varieties, such as the Bermuda, are poorly adapted to production in northern latitudes because of the unfavorable combination of day length and temperature during the growing season. For that reason, six of the varieties studied were obtained from the Texas substation at Winter Haven,[5] while all the others were grown at Ithaca, N. Y.

At Winter Haven, the usual cultural practices of that region were followed. The soil, a fine sandy loam, received an application of 250 pounds of 11–48–0 fertilizer per acre, and the necessary moisture was supplied by furrow irrigation. The onions were grown from seed, and the seedlings were set out in December. The mature bulbs were harvested in April, shipped to Ithaca by express, and analyzed for volatile-sulfur content within a few days after they were received.

At Ithaca, 10 varieties adapted to northern climates were grown on a gravelly sandy loam, which had received an application of 10 tons of manure and 1,500 pounds of a 5–10–5 fertilizer per acre. The onions were started from seed in February, and the seedlings were transplanted to the field the end of April and harvested during August and September. An overhead irrigation system supplied adequate moisture during periods of insufficient rainfall.

Because it is known that the stage of maturity has an influence on the degree of pungency, care was taken to harvest all varieties when they had developed their maximum content of volatile sulfur, or when the tops began to fall over and wilt. Analyses for volatile sulfur were made within 2 weeks after harvest. A composite sample from at least 25 bulbs was taken for analysis. Dry-weight determinations were made on 100-gm. aliquots dried in a ventilated oven at 60° C. for 48 hours.

The results of this study are presented in table 1, which lists the different varieties in ascending order of pungency based on the determinations made in 1937. Because the data for early varieties grown in Texas are hardly comparable with the data for those from New York, the varieties are grouped separately according to their source.

It will be noticed that, in general, the volatile-sulfur content of the onions was higher in 1936 than in 1937, probably because of differences in the prevailing climatic conditions. At Ithaca the growing conditions were more favorable for the development of the bulbs in 1936 than in 1937, as indicated by a considerable difference in the average weight of the bulbs of each variety at harvest time. More important is the fact that the order, or relative pungency, was the same for all of the early Texas varieties in both years, and that in the late varieties this order was changed only slightly in four of the varieties studied.

[5] The writers are indebted to Mr. L. R. Hawthorn of the Texas Experiment Substation No. 19, Winter Haven, Tex., for supplying the samples in 1936 and 1937.

TABLE 1.—*Volatile-sulfur content on a fresh-weight basis, percentage dry matter, and average fresh weight per bulb of 16 varieties of onions grown at Winter Haven, Tex., and at Ithaca, N. Y., in 1936 and 1937*

Variety and where grown	Results for 1936			Results for 1937		
	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content
Winter Haven, Tex.:	*Grams*	*P. p. m.*	*Percent*	*Grams*	*P. p. m.*	*Percent*
F. P. I. 106054				165.8	61.1	10.01
Early Grano	210.5	68.1	8.71	206.5	65.2	7.35
Yellow Bermuda	132.6	72.3	10.58	125.9	87.4	8.97
Crystal Wax	134.2	97.9	10.27	106.2	98.4	8.94
White Creole	57.2	129.1	19.20	69.3	127.6	8.63
Red Creole	81.2	155.3	19.40	70.2	143.1	9.69
Ithaca, N. Y.:						
Early Grano	220.1	67.5	6.97	148.7	59.5	7.22
Early Yellow Globe	239.4	94.4	9.53	152.6	72.5	9.82
Utah Sweet Spanish	393.6	97.9	7.89	221.0	78.7	6.87
Red Rocca				205.0	81.1	7.97
Mountain Danvers	306.8	126.6	10.72	143.6	88.2	9.42
Red Wethersfield	268.5	123.0	12.06	146.6	98.3	10.73
Brigham Yellow Globe	265.2	117.3	12.08	176.9	116.2	10.31
Yellow Globe Danvers	244.8	124.5	12.08	151.4	121.5	16.66
Ebenezer	156.0	156.9	14.88	122.0	134.1	13.92
Australian Brown				123.0	144.5	10.13

Early Grano, the only variety grown in both Texas and New York in this experiment, proved to be one of the mildest types in both groups. It was exceeded in mildness only by F. P. I. 106054. Red Rocca, suprisingly, was more pungent than some of the native varieties, although when imported from Italy it is known to be the mildest onion available. This suggests that under certain conditions the influence of soil and climate may be more important than genetic factors in determining the pungency of onions. Early Yellow Globe and the Utah Sweet Spanish are other varieties which, on the basis of these data, must be considered mild. In the medium-pungent groups should be listed the yellow Bermuda, Crystal Wax, Red Wethersfield, Brigham Yellow Globe, and Yellow Globe Danvers. Outstanding as pungent varieties are the Creoles, Ebenezer, and Australian Brown. Obviously these last-named varieties should be given first consideration in selecting stock for manufacturing purposes for which onions of extreme pungency are desired.

From a study of the moisture content of different varieties of onions. Jones and Bisson [6] drew the following conclusion:

> Evidently, those varieties that are considered mild and of rather poor storage quality have the highest moisture content, whereas those that are the most pungent and keep best in storage have the lowest moisture content.

This suggests that pungency in any variety is merely a matter of relative concentration of the dry matter, including onion oil. To some extent, this view is supported by the data in table 1, although it must not be overlooked that there are several notable exceptions. Australian Brown and F. P. I. 106054, the strongest and the mildest varieties included in the study carried out in 1937, both had a medium water content of 90 percent.

[6] JONES, H. A., and BISSON, C. S. MOISTURE CONTENT OF DIFFERENT VARIETIES OF ONIONS. Amer. Soc. Hort. Sci. Proc. 31: 165–168. 1934.

In this connection attention should be called to the fact that in these experiments there was fairly good correlation between the average fresh weight of the bulbs and their relative mildness.

EFFECT OF ENVIRONMENTAL FACTORS ON ONION PUNGENCY

TEMPERATURE

In 1936 an experiment was conducted in the greenhouse to determine the effect of temperature on the pungency of onions. Thirty plants of Yellow Bermuda were grown in each of several iron drums 22 inches in diameter and 17 inches in depth. The drums were filled with a sandy-loam soil; and by means of an automatic watering device, connected by glass tubing to the base of the drum, a water table 12 inches below the surface was maintained. Two drums were placed in each of three greenhouses, in which the respective temperature ranges were from 50° to 60°, 60° to 70°, and 70° to 80° F. The experiments were started in January and the bulbs were harvested in June. Because it was impossible during the last month of growth to maintain an average temperature below 70° in any of the houses, the data from this experiment must be considered as inconclusive. However, since such striking differences were obtained from the temperature treatments, the results of this exprciment are presented in table 2. According to these data, the onions grown at a temperature of from 70° to 80° were three times as pungent as those grown at from 50° to 60°. In evaluating these data, consideration must be given to the physiological age of the plants. At the time the onions were harvested the tops of the plants in the warmest house (70°–80°) had died down completely, whereas those in the coolest house (50° to 60°) were still growing vigorously. Differences in pungency in the three lots can therefore be attributed in part to differences in the stage of maturity. In an earlier paper [7] the writers pointed out that until the time when the tops begin to fall over the pungency of the bulbs increases steadily. Undoubtedly the results of this experiment would have been less striking if the bulbs from the three temperature treatments could have been harvested when the plants had all reached the same physiological age.

An attempt to repeat this experiment in 1937 failed because of serious damage to the plants by red spider and thrips at the high temperature.

TABLE 2.—*Volatile sulfur content on a fresh-weight basis, percentage of dry matter, and average fresh weight per bulb of Yellow Bermuda onions grown in the greenhouse at three different temperatures.*

Growing temperature [1] (°F.)	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content
	Grams	*P. p. m.*	*Percent*
50°–60°	65	42.8	8.37
60°–70°	74	80.0	7.98
70°–80°	46	130.9	7.38

[1] During the last month of growth, the temperature in all houses varied from 70° to 80°.

[7] See footnote 4.

WATER SUPPLY

Seedlings of Early Grano, Ebenezer, and Utah Sweet Spanish were transplanted to the field late in April 1936. The sandy-loam soil received an application of 10 tons of manure and 1,500 pounds of a 5–10–5 fertilizer per acre. The rows of each variety were so arranged that one-half of each row could be supplied with additional water by overhead irrigation. During the growing season of May 1 to September 1 a total of 9.41 inches of rain fell. One-half of each row received sufficient irrigation to provide in all about 1 inch of water a week, or a total of 17 inches during the growing season of 4 months. When the tops had fallen over, the bulbs were harvested and their content of volatile sulfur determined. The data are presented in table 3. In every instance the bulbs grown with additional water were larger and less pungent than those which had been dependent on the natural rainfall. The reduced pungency of Early Grano and Ebenezer as a result of irrigation was due in part at least to the higher water content of the irrigated bulbs, which tended to reduce the concentration of volatile sulfur in the bulbs when the data were expressed on a fresh-weight basis.

TABLE 3.—*Effect of irrigation on the average weight of bulbs, the content of volatile sulfur on a fresh-weight basis, and the percentage of dry matter of onions of three varieties*

Variety	Water supply	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content
		Grams	*P. p. m.*	*Percent*
Early Grano	Not irrigated	154.2	82.5	7.35
	Irrigated	220.1	67.5	6.97
Ebenezer	Not irrigated	77.5	162.3	15.42
	Irrigated	156.0	156.9	14.88
Utah Sweet Spanish	Not irrigated	208.4	103.6	7.72
	Irrigated	393.6	97.9	7.89

No doubt the effect of irrigation on the pungency of the bulbs depended on the increase in available soil moisture. If the natural rainfall had been higher during that particular season, differences in pungency between irrigated and nonirrigated lots would probably have been negligible.

SOIL TYPES AND WATER SUPPLY

In the second experiment the influence of soil types and water supply were studied in the greenhouse at an average weekly temperature of 60°–70° F. Iron drums 22 inches in diameter and 17 inches in depth were used as containers for the soil. Four drums were filled with a well-decomposed woody peat, four with a sandy loam, and four with a sandy soil. In two drums of each soil type the water table was maintained 12 inches below the surface; in the remainder it was held at a depth of 16 inches. The water table was controlled by means of an automatic watering device connected by glass tubing to the base of the drum. The low water level provided adequate moisture for the growth of the onions in the peat soil without surface application of water. It was found necessary, however, to add occasionally an equal quantity of water to the surface of each of the drums containing

sandy loam and sandy soil at a low water level in order to maintain growth.

Fertilizer of 5–10–5 analysis was added to each drum at the rate of 1,000 pounds per acre. In October 1936, 30 sets of Yellow Globe Danvers were planted in each drum. Beginning in January 1937 a 15-hour photoperiod was provided by means of Mazda lights. The bulbs were harvested in May 1937, and their content of volatile sulfur was determined. The data in table 4 indicate that the higher content of soil moisture increased the average weight of the bulbs and decreased the volatile-sulfur content when compared with bulbs grown at a low water table. These experiments are in agreement with those obtained outdoors in experiment 1. There was also a marked difference in the pungency of the bulbs, depending on the soil type in which they were grown. The most pungent onions were harvested from the peat, the mildest from the sandy soil.

TABLE 4.—*Effect of soil type and sulfur content and of the water supply on the average weight of bulbs, the content of volatile sulfur on a fresh-weight basis, and the percentage of dry matter of Yellow Globe Danvers onions, grown in the greenhouse*

Soil type	Approximate percentage of sulfur in the soil	Water supply	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content
	Percent		*Grams*	*P. p. m.*	*Percent*
Peat	0.470	Low	40.4	101.4	12.56
		High	51.8	85.8	12.90
Sandy loam	.039	Low	26.6	80.3	13.19
		High	60.1	74.9	12.84
Sandy soil	.004	Low	41.0	64.0	13.01
		High	50.0	49.5	12.88

The approximate values for the total sulfur content of the three soil types used in this experiment are included in table 4. These data are averages determined for New York soils by Wilson and Staker[8] and by Bizzell.[9] The addition of the equivalent of 1,000 pounds of 5–10–5 fertilizer per acre to the drums did not change these values appreciably.

A striking correlation exists between the pungency of the onions and the soils on which they were grown. However, this relationship is by no means proportional. Whereas the sandy loam contains roughly 10 times and the peat 100 times as much sulfur as the sandy soil, the corresponding volatile-sulfur content of the onions was only 25 and 58 percent higher on the sandy loam and peat than it was on the sandy soil. It should be remembered that the sulfur analyses of the different soil types include both available and unavailable forms of sulfur. These comparisons are based on determinations made for pungency of onions grown with a low water supply. A similar relationship exists between those grown on soils with a high water table.

APPLICATION OF SODIUM SULFATE

Drums similar to those used in the previous experiment were filled in duplicate with a well-decomposed peat, a clay loam, and a sandy loam. Bank sand was placed in four additional drums. All were

[8] WILSON, B. D., and STAKER, E. V. THE CHEMICAL COMPOSITION OF THE MUCK SOILS OF NEW YORK. N. Y. (Cornell) Agr. Expt. Sta. Bul. 537, 26 pp. illus. 1932.

[9] BIZZELL, J. A. THE CHEMICAL COMPOSITION OF NEW YORK SOILS. N. Y. (Cornell) Agr. Expt. Sta. Bul. 513, 25 pp., illus. 1930.

fertilized with an equivalent of 1,000 pounds of a 5–10–5 analysis per acre. In addition, two of the drums containing bank sand received an application of sodium sulfate at the rate of 600 pounds per acre. The water table was maintained automatically at a level of 16 inches below the surface in all drums. Only distilled water was used for irrigation. Yellow Bermuda were transplanted, 30 to a drum, in October 1937; the mature bulbs were harvested in May 1938. The temperature of the greenhouse was maintained at 60° to 70° F. and the daily photoperiod lengthened as in the previous experiment. The data in table 5 again show that onions grown on peat soil are not only larger but also considerably more pungent than those from other soil types. The smallest and mildest onions were harvested from sand and sandy loam soil.

TABLE 5.—*Effect of soil type and of sulfate content of the soil on the average weight of bulbs, the content of volatile sulfur on a fresh-weight basis, and the percentage of dry matter of Yellow Bermuda onions grown in the greenhouse*

Soil type	Approximate percentage of sulfur in the soil	Average fresh weight per bulb	Volatile-sulfur content	Dry-matter content
	Percent	*Grams*	*P. p. m.*	*Percent*
Peat	0.470	63.2	157.2	11.11
Loam	.058	48.2	125.2	10.42
Sandy loam	.039	39.3	86.4	10.58
Sand (low sulfate)	.004	20.4	72.8	8.77
Sand (high sulfate)	.008	30.6	77.6	8.70

Again there was a direct relationship between the pungency of the bulbs and the sulfur content of the soils on which they were grown. The addition of an equivalent of 600 pounds of sodium sulfate per acre to the sandy soil doubled the percentage of sulfur present but was insufficient to have an appreciable effect on the pungency of the onions. At any rate, the slight increase in volatile sulfur of the bulbs from sand to which sulfate had been added is probably not significant.

These results lead to the conclusion that on a commercial scale it is not feasible to increase the pungency of onions by the addition of fertilizers of a high sulfur content because the quantities required to produce a noticeable effect is unreasonably large.

STORAGE

Experiments to study changes in the pungency of onions held in cold storage were undertaken in 1936 and 1937. Yellow Globe Danvers and Utah Sweet Spanish were stored in bushel crates and kept in an experimental cold-storage room at 33° F. Temperature fluctuations in the room did not exceed ±1.5°. At intervals samples were taken for analysis to determine changes in the content of volatile sulfur and moisture. At the same time, records were taken of the shrinkage that occurred during the different storage periods. Since the bulbs showed neither spouts nor decay none were discarded during the storage period; consequently shrinkage data represent weight losses only.

The results of these experiments are summarized in table 6. It will be noticed that the volatile-sulfur content increased as the storage

period progressed. However, this increase in pungency appeared to proceed at a slower rate toward the end of the storage period; in fact, the lot of Yellow Globe Danvers stored in 1937–38 showed a slight decrease in its content of volatile sulfur.

Shrinkage losses and changes in the percentage of dry matter are partly responsible for variations in the volatile-sulfur content of the different samples. However, table 6 reveals that these two factors alone cannot account for the general tendency of volatile sulfur to increase during the storage period. Instead, it is evident that some of the onion oil was formed during storage from other forms of sulfur and organic constituents in the bulbs.

TABLE 6.—*Shrinkage, content of volatile sulphur on a fresh-weight basis, and percentage of dry matter of onions of two varieties when held in storage at 33° F. for different periods*

Variety	Date sampled	Shrinkage	Volatile-sulfur content	Dry-matter content
		Percent	*P. p. m.*	*Percent*
Yellow Globe Danvers	Sept. 17, 1936	----------	110.1	11.52
	Oct. 5, 1936	----------	128.6	11.34
	Nov. 5, 1936	----------	138.2	10.92
	May 15, 1937	----------	139.6	10.09
Utah Sweet Spanish	Aug. 30, 1937	0.	78.7	6.87
	Sept. 28, 1937	1.77	96.3	8.50
	Nov. 4, 1937	2.66	96.8	6.91
	Dec. 21, 1937	7.65	113.0	6.72
Yellow Globe Danvers	Sept. 27, 1937	0.	114.2	7.11
	Nov. 3, 1937	.42	125.2	8.16
	Dec. 20, 1937	2.68	151.4	8.25
	Feb. 22, 1938	3.72	144.2	7.83

SUMMARY

This study is concerned with the pungency of onions as affected by inherited characteristics, growing temperature, soil type, water supply, and storage. The relative pungency of different samples was measured by determining chemically the volatile-sulfur content of the bulbs and thereby their content of onion oil, which is the substance that gives the onion its characteristic pungent taste and odor.

Of the different factors studied, the inherent characteristics of the varieties examined had the most pronounced influence on pungency. Some varieties were found to contain nearly three times as much volatile sulfur as others. On a dry-weight basis, these differences were much smaller, showing that to some extent relative pungency is merely a question of concentration of dry matter.

An experiment in which onions were grown at different temperatures indicates that the pungency of onions tends to increase as the average temperature is raised. However, the results of this experiment must be considered as inconclusive.

Next to variety, the type of soil on which the onions were grown was the most important factor in determining pungency. Onions grown on a peat soil were roughly twice as pungent as the same variety grown on a sandy soil, while onions on loam or a sandy loam were intermediate in pungency. There was a direct correlation between the volatile-sulfur content of the onions and the total sulfur content of the soil on which they were grown. However, this relationship was

not proportional. Where the percentage of sulfur in sandy loam was about 10 times as high as in sandy soil, the corresponding difference in the volatile-sulfur content of the bulbs was only 25 percent.

Overhead irrigation or a high water table always caused a small, but consistent, lowering of the volatile-sulfur content of the bulbs, and this was associated with a pronounced increase in the size of the bulbs grown with an abundant supply of moisture.

In cold storage, over a period of several months onions slowly increased in pungency. This increase may be accounted for in part by the loss of water and carbohydrates as a result of transpiration and respiration.