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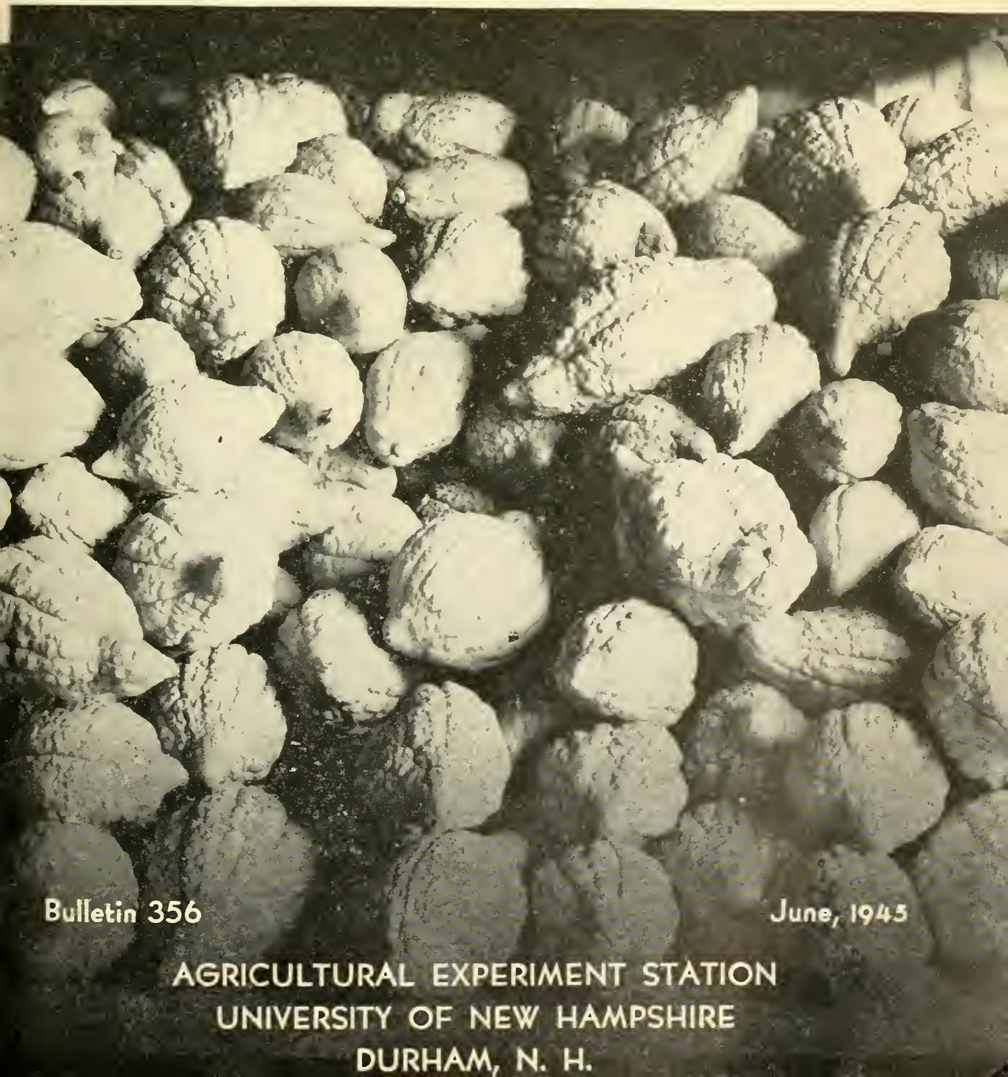

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TABLE OF CONTENTS

The Storage of Blue Hubbard Squash

by

A. F. Yeager, M. C. Richards, T. G. Phillips, Tatiana Levcowich, and Raymond W. Barratt

MOST of the squash produced each year in New Hampshire cannot be used at harvest time. Thus, the problems of keeping the squash without loss from diseases and in an edible condition are of interest both to the grower and consumer. It is possible to store squash, as is demonstrated by the New England tradition of squash pie for Thanksgiving and New Year's Day. The grower who can store squash after December gains greatly, for studies show that prices usually increase after that time. The consumer also gains in that the consumption period for squash is lengthened.

Experiments on squash storage have been conducted by Cummings *et. al.* (3, 4), Stuart (7), and others. The diseases causing squash rots in storage have been studied by Boyd (1, 2), Guba and Gilgut (5), and Ramsey *et. al.* (6). Individual growers have also studied the problems of squash storage and have arrived at varying conclusions as to the best methods and means of storing Blue Hubbard squash.

Squash Storage Tests in 1941

The first squash storage experiments at the University of New Hampshire were made in 1941, when a test was undertaken to determine the effect of stem length on keeping. At that time, certain New Hampshire growers considered it necessary to leave a piece of the vine on each side of the stem when the squash was harvested, a custom not common elsewhere. To determine whether this was desirable, 50 squash were cut leaving a part of the vine on each side of the stem attached to the fruit. An equal number were cut leaving a stem of several inches but no attached vine. Data taken on the amount of spoilage showed no measurable difference in losses between the two methods. A considerable amount of spoilage occurred, in both cases, at the stem end. Healthy squash lost about 15 per cent weight during the storage period, September 20, 1941, to February 15, 1942.

1942 Experiments

In the spring of 1942, more elaborate storage experiments were planned. A special field of Blue Hubbard squash was planted for test purpose. Shelves were constructed for storage purposes. Several objectives were chosen for investigation, one of which was to find the effect of the maturity of the squash on keeping quality. To determine this, squashes which set on the vines before the first of August, classed as *early set*, were marked by scratching the skin. Others which set between the first and fifteenth of August were also marked and called *medium*. Other fruits which set after the first of August, but which appeared to be well matured at harvest, were classed as

Fig. 1.—Squash piled for preliminary curing, a common but detrimental practice.

late set. All of them were harvested on September 20. Twenty-five squashes were used in each treatment. Since it was the custom for squash growers in New Hampshire to pile their squashes in the field for two weeks covered with vines to cure before moving to storage *(Figure 1)*, this treatment was used for most of those harvested in 1942 and was the standard treatment. Some lots were moved directly from the field to storage without field piling and one lot was put into the greenhouse at harvest time for two weeks' curing before being moved to the permanent storage. One lot of squash was taken from vines which had been dusted with C.O.C.S.*. Other squashes were treated with fungicides after harvesting and just before being placed in storage. Some squash taken directly from the field and some that were piled were bruised with the butt of a nailing hatchet. The bruises were deep enough to be seen, but not deep enough to sink the head of the nailing hatchet into the fruit. Squash were also stored in several places, the principal place being the apple-receiving room where the grading of the apples for storage is done. Some were stored in the regular apple cold storage room; others were stored in a modified atmosphere apple storage where the CO_2 content was increased to about 11 per cent and the oxygen content was maintained at about the same level. Another lot was stored in a potato cellar. The tabulated results in Table 1 show the percentage of squash which spoiled at each period of examination.

1942-1943 Results

The data in *Table 1*, while not conclusive, do show a few significant points. The squash taken directly from the field, instead of being field-piled, kept much better. Those which were greenhouse-cured also seemed to keep better than the others. Those which were well-matured, but not over mature, kept a little better than the im-

*Copper Oxychloride Sulphate

Table 1.—Effect of Treatments upon Losses of Squash in Storage. 1942-43.

Treatments Apple Receiving Room Temp. 60°-75°F. Humidity 50-60%	Per Cent Removed by Dates Given Nov. 23	Dec. 21	Jan. 27	Feb. 15
1. Early set, field piled	12	56	64	68
2. Medium set, field piled	16	44	44	56
3. Late set, field piled	4	44	80	84
4. Direct from field, carefully handled	8	20	24	32
5. Direct from field, bruised	4	36	44	48
6. Field piled, bruised	40	76	80	88
7. Greenhouse cured two weeks	4	24	32	40
8. Dusted with COCS in the field, field piled	16	44	48	60
9. Field piled, treated with Borax	12	36	68	84
10. Field piled, treated with Fermate	0	28	40	56
11. Field piled, treated with Thiosan	12	24	40	44
12. Field piled, treated with Phenothiozen	12	36	64	68
Apple Cold Storage Temp. 35°-40°F. Relative Humidity 80-85%				
13. Medium mature, field piled	20	72	100	100
14. Medium mature, field piled Modified air apple cold storage	28	32	92	100
Potato Storage Temp. 32°-38°F. Relative Humidity 85-99%				
15. Medium mature, field piled	not noted	60	100	100

In treatments 9, 10, 11, 12, the fruits were dipped in solutions of the fungicides just before being placed on the shelves at storage time. Borax was used at 1 per cent concentration plus a wetter. Fermate, Thiosan, and Phenothiozen were each .5 per cent concentration with wetting agents added.

mature or over ripe squash. Of the other treatments, the squash kept in the apple-modified-atmosphere room and those stored in the regular apple storage spoiled early. Those in the potato storage also decayed sooner than those in the receiving room. Bruised squash showed more than average spoilage. Even the best treatment resulted in losses up to 40 per cent by the end of the 148-day storage period.

Fig. 2.—Black rot, a common storage disease.

Table 2.—Losses from Organisms under Two Different Storage Conditions, 1942-43

	Warm Storage* Temperature 60°-70° F. Relative Humidity 30-60 Per Cent	Cold Storage** Temperature 32°-42° F. Relative Humidity 85-95 Per Cent
	Percentage Loss	Percentage Loss
Rhizopus sp.	12.12	5.00
Alternaria sp.	1.26	38.00
Fusarium sp.	31.26	43.00
Mycosphaerella citrullina	53.26	4.00
Botrytis sp.	——	20.00
Unknown	2.10	——

*Data on 300 Blue Hubbard squash
**Data on 100 Blue Hubbard squash

The organisms causing squash rots were found to differ in type and intensity under the various storage conditions. *Figure 2* shows a black rot lesion, as it developed on the side of a Blue Hubbard squash in the warm storage. *Figure 3* shows the numerous lesions which developed under cold storage conditions. These lesions are caused by Fusarium and Alternaria or Cladosporium followed by Alternaria.

In *Table 2*, it will be noted that in the warm storage 60°-70° F., Rhizopus, Fusarium, and Mycosphaerella, causing respectively the diseases known as soft rot, dry rot, and black rot, were the important agents causing spoilage.

In the cold storage 32°-42° F., Rhizopus became less important, but a soft rot developed caused by a Botrytis. Dry rot caused by *Mycosphaerella citrullina* was of little importance. Certain squash showing black rot lesions were placed in cold storage; these spots did not increase in size during the storage period. Fusarium, Alternaria, and Botrytis were responsible for the major losses under cold storage conditions.

Since black rot was the most important disease under normal storage conditions, data were taken to determine where infections from this disease occurred on the fruits. See *Table 3*.

The outstanding feature of these data is the high proportion of stem-end infections. Side infections at uninjured places or very small

Table 3.—Losses in Storage from Black Rot, 1942-43. Data Showing Where Infection Occurred

Storage Period	Black Rot Infections: Side	Stem	Blossom end	At injuries	Number squash lost out of 300
	Percentage Losses				
Oct. 26-Nov. 30	25.0	16.6	8.3	50.1	12
Nov. 30-Dec. 28	7.6	86.6	1.9	3.9	92
Dec. 28-Feb. 1	32.7	56.9	8.6	1.8	28
Feb. 1-March 1	52.0	40.0	8.0	—	25
Average loss	29.3	50.0	6.8	13.9	

unnoticed injuries result in much more spoilage than from obviously injured places. Spoilage after injuries mostly occurred early. Therefore, any method of reducing stem infections should be of great importance.

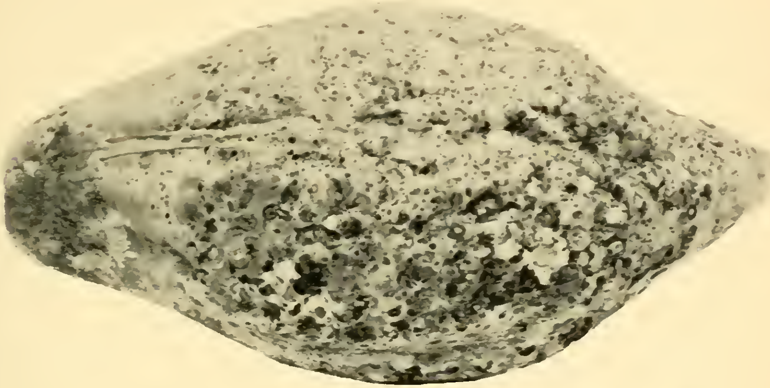

Fig. 3.—A squash stored at near freezing temperature, showing the typical storage rots developing under these conditions.

The 1943-1944 Experiments

Despite the lack of success with cold storage in 1942-43 and because of the observation that certain of the storage rots which occurred at high temperatures failed to develop at low temperatures, it was thought that perhaps by proper handling these could be eliminated and that cold storage might yet be feasible; hence, this was repeated with variations. The squash crop in 1943 was generally immature; therefore, only the more mature specimens were selected for the experiment, and no attempt was made to separate them into degrees of maturity. Because of the large number of infections which had been noted as occuring at the stem end, it was decided this year to see if removing the stem altogether might not be beneficial. Therefore, with some of the squashes the stems were gouged out, since it did not seem to be feasible to cut the stem off close to the squash with a knife. Some of these gouged places were not treated, others were dusted with Fermate or C.O.C.S.

The 1943-1944 Results

As will be noted by an examination of *Table 4*, removing the stems decreased the amount of spoilage. In one test, C.O.C.S. applied to the cut surfaces caused some injury. Squash taken directly from the field to storage kept better than those that were field-piled. Bruising resulted in greater losses than cutting, when the cutting was done by hacking each squash with an ax to at least 1/2 inch in depth. In this test, the bruising was extremely severe, the head of the nailing hatchet being sunk below the surface of the squash. The figures on the number of squashes which spoiled when cut with an ax does

Table 4.—Squash Losses under Two Different Storage Conditions, 1943-44

Storage A. Temperature 60°-75°F. Relative Humidity 30-60 Per Cent. Stored 9/21/43

Treatments	Percentage Removed by Dates Given Nov. 22	Nov. 29	Dec. 13	Jan. 24	Feb. 1
1. Direct from field to storage	40	40	55	70	70
2. Field piled 14 days	60	45	55	60	75
3. Greenhouse piled 14 days	5	5	5	5	20
4. Greenhouse piled 14 days + COCS*	25	25	35	50	50
5. Greenhouse piled 14 days + Fermate*	30	30	30	45	50
6. Greenhouse piled 14 days + Elgetol**	35	35	50	60	60
7. Direct from field cut with ax	55	60	70	70	75
8. Direct from field bruised	100	100	100	100	100
9. Direct from field, stems removed	20	20	35	35	35
10. Direct from field, stems removed, stem end dusted with COCS	15	15	35	35	35
11. Direct from field, stems removed, stem end dusted with COCS	45	45	50	50	50

Storage B. Temperature 32°-40°F. Relative Humidity 85-90 Per Cent. Stored 9/21/43

	Percentage Removed by Dates Given Nov. 22	Nov. 29	Dec. 13	Jan. 24	Feb. 1
1. Direct from field to storage	60	100	100	100	100
2. Field piled 14 days	85	90	100	100	100
3. Greenhouse piled 14 days	0	35	100	100	100
4. Greenhouse piled 14 days + COCS*	10	40	100	100	100
5. Greenhouse piled 14 days + Fermate**	5	45	100	100	100
6. Greenhouse piled 14 days + Elgetol**	65	100	100	100	100

*Dust
**Liquid 1 per cent Elgetol
Treatments 7-11 in Storage A, not duplicated in Storage B

not give a true picture, because very little of the spoilage took place near the cuts. It occurred mostly at other places on the fruit; hence, infection did not take place through the cuts. The least spoilage occurred in the greenhouse-treated lot. One fact definitely demonsrated by this year's work was that storage at 32° to 40°F. is not feasible for squash. All of the fruits spoiled at these temperatures by December 13, even a lot placed in a barrel with calcium chloride, which reduced the humidity to 40 per cent, was affected at the same time by the same diseases as those exposed to the higher humidities at these temperatures. The best treatment showed 20 per cent loss by February 1, 1944.

The 1944-1945 Experiments

The 1944 crop of squash was grown on land where no squash had been grown for two years. The fruits selected were well-matured specimens. Since the apple-receiving room was thought to be maintained at too high a temperature for best squash storage and this could not be remedied, another room was provided. A uniform temperature of 50°F. near the door and 60°F. at the top of the shelves was maintained. These temperatures were thought to be about right for Blue Hubbard squash storage. The humidity was maintained at from 20 to 50 per cent. In order to avoid bruising the squash by frequent examinations, they were left in place on the racks far enough apart so that they could be inspected from all sides without moving them. When evidence of spoilage occurred, the fruits were removed. This year's experiment was conducted under what might be called optimum storage conditions so far as we know them. The stems in one lot of squash were removed close to the fruits with a pruning saw. Other squash were bruised by hitting them with a wide, smooth board; no skin breakage occurred. Squash left uncovered in the field and injured by frost were also placed in storage. Thermocouples connected to an automatic recording instrument showed that the air temperature, on the night that injury to the squash occurred, was 28°F., but the temperature underneath the skin on the top of the squash dropped as low as 22°F.

Fig. 4.—A squash with stem gouged out, after five months' storage. Note that cut area has healed over.

1944-1945 Results

The results of the storage experiment as compiled in *Table 5*, largely confirm expectations. The crop as a whole kept well with the temperature at 50°-60°F. and low humidity 20-50 per cent. The short-stemmed squash kept better than the long-stemmed ones. Those taken directly to storage kept better than the field-piled ones. Since the best of those taken directly to storage kept perfectly, greenhouse curing for two weeks could not be expected to make them better, but they did give perfect storage. The heat in the greenhouse at one point reached 120°F., which, while not recommended, obviously did no serious damage. Greenhouse-stored squash showed more yellowing by February 7 then those not cured, probably because the heat treatment hastened maturity. Cutting with an ax caused some loss, but not as much as bruising There was considerable loss from frosting, partly by admitting disease and partly by physical damage to the fruit, which caused cracking and dying and made it unmarketable. The general effect was much the same as bruising with a smooth board. The immature squashes kept well, but because of their immaturity were not what would be classed as marketable squash at the time the storage experiment was completed on February 7.

Table 5.—Losses in Storage, September 22, 1944, to February 7, 1945
Temperature 50°-60°F. ..Humidity 20-50 Per cent

Treatments	Percentage Removed	
	Diseased	All causes
1. Field to storage - short stems	0	0
2. Field to storage - long stems	12	20
3. Field to storage - Formaldehyde dip*	0	0
4. Field piled 14 days	12	12
5. Field piled 14 days, then dipped in Formaldehyde	8	20
6. Greenhouse piled 14 days, then to storage	0	0
7. Field to storage + cut with ax	8	12
8. Field to storage + bruised with board	20	20
9. Frosted in field before storage	16	32
10. Immature	0	32

*Two per cent concentration
Short stems in all cases except where indicated

The Effect of Apples

Another test conducted this year was to determine whether early yellowing of the squash in previous years, when stored in the apple-receiving room, might be due to gas from the apples. To determine this, several squash were placed in a closed box in the storage with half a bushel of ripe apples. An equal number were placed in a similar box, but without apples. The ones associated with apples turned yellow within four weeks, the others did not. Following this, a test was made to see if Ethylene gas might produce this result. Releasing Ethylene in a barrel with green squash in January produced no visible effect. It seems, therefore, that squash after that length of storage were not susceptible to the treatment or else some other respiration product of apples is the cause.

Field Observations

While controlled conditions offer much the best source of reliable information, observations made elsewhere deserve mention.

During the three years many trips were made to home and commercial storages to inspect squash and to check conditions. The large storage of the Merrimack Farmers' Exchange at Derry was particularly good for our purpose because squash there were brought in by many growers whose conditions of culture, seed, and handling methods differed from each other.

This offered an opportunity to check various factors. Whether field piling was detrimental as experiments indicated was one of these.

Table 6.—Losses in a Commercial Storage on Blue Hubbard Squash at End of 60 Days. 1943

Farm	Field piled Percentage disease losses all causes	Farm	Not field piled Percentage disease losses all causes
A	45	G	15
B	33	H	15
C	25	I	50
D	25	J	20
E	22	K	10
F	45	L	12
Average	32.5		20.3

Table 6 gives the results of a comparison of six crops which were field-piled before storage and six which were not.

The average per cent loss of the two groups shows 12½ per cent better keeping for those not field-piled. The fact that one grower's product in the lots not field-piled was very bad prevented this difference from being much greater. Except for this one exception, no grower in this group had as great a loss as the best one in the field-piled group.

A check against the experimental results in regard to temperatures was possible in one storage in which heat was maintained by a stove. Here, in the part of the storage near the stove, black rot was

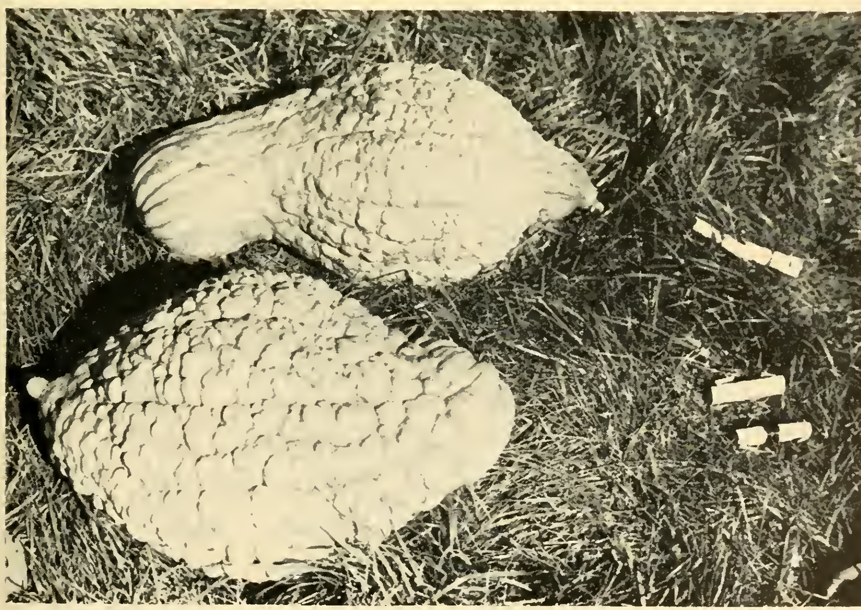

Fig. 5.—Squash exposed on a frosty night to determine the comparative air and squash surface temperatures. These specimens have had their stems cut short, as recommended.

serious, but no Fusarium rot was present. At a remote corner when the temperature was near freezing, a little black rot was in evidence, but many squash had decayed from Botrytis, Alternaria, and Fusarium.

A general observation in support of which no figures can be presented is that medium-sized squash of 15 to 20 pounds weight seemed to keep better than the lots of oversized specimens. This is a reasonable expectation since squash ovaries at blossom time already have their full number of cells. Increase in size thereafter comes from enlarging these cells. Therefore, an oversized squash would probably have larger and more easily crushed cells than a smaller specimen. The extra weight of large specimens resting on a small area might bring about more bruising and more loss.

Respiration Losses

Figures in later years confirmed the first year's results in that a loss in weight of about 15 per cent may be expected in specimens which do not decay during a six-month-storage period.

Preliminary chemical studies of the 1943 crop show approximately the changes presented in *Tables 7 and 8*. More detailed results from the 1944 crop will be published when the analysis of the numerous samples is completed.

Table 7.—Amount of Squash Remaining After Storage in Per Cent. 1943-44

	Start	14 days	97 days	170 days
Total weight	100	95	87	85
Total solids	100	77	68	56
Starch and Sugars	100	69	52	33

We note from *Table 7* that, while the total weight decreases by only 15 per cent, the solids decrease 44 per cent and the carbohydrates 67 per cent. Thus, a pound of squash becomes continually less valuable as an energy food as the season progresses.

Even this does not tell the whole story. *Table 8* shows what has happened to the solids themselves during this time.

In addition to the actual loss in solids from 13 to 8 per cent, which means an increase in moisture per cent from 87 to 92 per cent, the story told by these data is a rapid change of the starch to sugar. We might thus expect a squash to taste sweeter after some storage

Table 8.—Chemical Changes in Blue Hubbard Squash in Storage. 1943-44

	Start	14 days	97 days	170 days
Actual Per Cent Squash that is solids	13	10+	10−	8
Per Cent of Solids that is sugar	29	42	56	53
Per Cent of Solids that is starch	41	24	1	0

than at first. This was thought to be true from tests made, although tasting samples at three-month intervals can hardly be an accurate way of comparing them. In 1944-45, squash were canned at each of the chemical sampling dates. Then, when all were available, the canned product from all lots was given a direct comparison. The results confirmed what had been expected; namely, that squash stored three months was sweeter and more moist than that canned after two weeks' storage. It was also sweeter than that canned after six months' storage and the color was brighter than the squash stored only two weeks. Therefore, it would seem desirable, before processing, to store squash for a time before canning or freezing.

One large specimen, secured from George H. Jackman of Alton, N. H., which had been stored two full years was found to be excellent in appearance but very poorly flavored when cooked; this was also true of specimens of our own kept a full year.

Summary

When Blue Hubbard squash were stored at temperatures of 60°-70°F. and relative humidities of 30-50 per cent, the organisms causing losses were black rot *(Mycosphaerella citrullina)*, soft rot *(Rhizopus nigricans)*, dry rot *(Fusarium sp.)*, bacterial soft rot *(Erwinia trachephila)*. Under storage conditions of 35-40° F. and humidities as low as 20 per cent or as high as 90 per cent losses were caused chiefly by Alternaria, Fusarium, and Botrytis. Losses from black rot were greatly reduced at the lower temperatures.

Blue Hubbard squash did not keep well in cold storage 35°-40°F. in our tests and the fruits were severely infected at the end of 70 days of storage.

Black rot was the most important disease causing losses. It accounted for 40-50 per cent of the losses during the period October 26—November 23, 80-90 per cent from November 30—December 28, 80-90 per cent from January 1—February 1, and 60 per cent from February 8—March 1.

Black rot infections were found on the fruits as follows: side 29 per cent, stem end 50 per cent, blossom end 7 per cent, and at injuries 14 per cent.

The following recommendations, based on three-year-storage trials, are made for the handling and storage of Blue Hubbard squash:

1. Move the squash directly from the field to storage. Do not leave them in the field to cure.

2. Remove both the mature and marketable-immature squash before frosts occur.

3. Remove the stems completely. This will prevent stem-end infection from black rot and Fusarium dry rot.

4. Handle squash carefully. "Clean" cuts in the fruits often heal over. Bruises do not, especially if the skin is broken.

5. Drying the squash thoroughly during the first two weeks of storage is essential to good keeping. This can be

done by heating the storage to 80°F. and circulating the air in the storage.

6. Blue Hubbards do not keep well in storages where the temperature is below 45°F., even with humidities as low as 20 per cent.

7. Liquid and dust fungicides applied to the fruits have not proved valuable in controlling storage rots. Fumigation of the fruits by gases was not tried.

8. Do not store squash near apples as the squash skins turn orange-yellow in color.

References

Boyd, O. C. *Why Do Winter Squash Rot in Storage?* Market Growers Jour. 50: 176-178. 1932.

Boyd, O. C. *The Squash Storage Disease Situation in Massachusetts.* Market Growers Jour. 53 (1): 218-220. 1933.

Cummings, M. B. *Some Hubbard Squash Experiments.* Market Growers Jour. 32: 41. 1923.

Cummings, M. B. and Jenkens, E. W. *Hubbard Squash in Storage.* Vermont Agr. Exp. Sta. Bul. 251: 1-35. 1925.

Guba, E. F. and Gilgut, C. *Causes and Control of Decay of Winter Squash in Storage.* Massachusetts Agr. Exp. Sta. Bul. 339: 25-26. 1937.

Ramsey, G. B., Wiant, J. S., and Link, G. K. K. *Market Diseases of Fruits and Vegetables: Crucifers and Cucurbits.* U. S. Dept. of Agr. Misc. Pub. 292: 55-58. 1938.

Stuart, William. *Moisture and Decay in Hubbard Squash in Storage.* Vermont Agr. Exp. Sta. Bul. 136: 214-215. 1907.

Bulletins and Circulars — Agricultural Experiment Station
February 1944 - June 1945

Station Bulletin 354—Agricultural Research in New Hampshire (November, 1944)

Station Bulletin 355—Pre-~~War~~ harvest Apple Drop With Special Reference to the McIntosh (June, 1945)

Station Circular 67—Small Grains and Variety Tests (February, 1940)

Station Circular 68—A Preliminary Report on Cobalt Treatment of a Nutritional Disease in New Hampshire Dairy Cattle (September 1944)

Station Circular 69—The Effects of Temperature, Soil Reaction, and Soil Nutrients on the Growth of Gerbera in the Greenhouse (December, 1944)