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"DEHYDRATION OF VEGETABLE FOODS; STUDIES WITH ONIONS".

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DEHYDRATION OF VEGETABLE FOODS: STUDIES WITH ONIONS

A B S T R A C T

Various temperatures and air velocities were used for dehydrating onions and their effect on the drying rate compared. The maximum temperature and air velocity was 75°C and 1,400 feet per minute, whilst the minimum temperature and air velocity was 50°C and 400 feet per minute.

The effect of the varying temperatures and air velocities on the volatile sulphur, ascorbic acid and sugar contents of the dehydrated onions was studied.

The most favourable temperature and air velocity at which the loss in the volatile sulphur content was at its minimum was found to be 60°C and 500 feet per minute.

The minimum loss in ascorbic acid occurred in samples dehydrated at 60° and 400 feet per minute.

Different varieties of onions were dehydrated during the season 1951 and 1952 and their volatile sulphur, ascorbic acid and sugar contents were determined.

Several onion varieties were imported from France and Egypt in 1951. Their seeds were grown at Harlington the following season and different constituents were compared with the imported ones.

The effect of the stages of maturity on the same

constituents of the different varieties was studied. The volatile sulphur and sugar content increased as the onions approached maturity, the ascorbic acid content decreased throughout the stages of maturity.

Onion varieties were stored for three months under normal conditions and the effect of storage was studied on the different constituents of the onions.

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CHAPTER I.

REVIEW OF LITERATURE

THE DEHYDRATION OF VEGETABLE FOODS

The drying of foods is a very ancient practice. Figs, raisins, other fruits, and meat preserved in this way were probably used by man at an early stage of his development. There is, however, little early literature available on the subject.

According to Prescott (1) desiccated vegetables, compressed into briquette form, were used to prevent scurvy among Union troops during the Civil War in the U.S. Prescott also mentioned the desiccated soup vegetables used successfully by the British army during the Boer War. During World War I according to Nichols (2) and his associates, the number of pounds of dehydrated vegetables shipped to the U.S. army overseas was as follows: potatoes 6,437,430 pounds; onions 336,780; carrots 214,724; turnips 56,224; and soup mixture 1,860,000 - a total of 8,903,158 pounds.

Dehydrated vegetables should have a low moisture content usually under 5 per cent. to minimize the deterioration in

colour, odour and flavour caused by oxidative and other chemical changes. They should be free from scorched flavour and the darkening caused by too severe heat treatment.

Dehydration greatly lessens the weight, reducing root vegetables to about one fifth of their fresh weight, leafy vegetables and tomatoes to one fifteenth or less. The bulk especially if the dehydrated products are compressed before packaging is much less than that of other forms, Cruess and Mackinney (3). One cargo ship can carry dehydrated vegetables equivalent to 5 to 15 ship loads of the fresh or canned - an important consideration during the shortage of ships. The dehydrated vegetables do not require refrigeration during shipment or storage. Because of the reduced weight and volume, less packaging material is needed per unit of food. Tin containers need not be used - a great advantage during the scarcity of tin.

Varieties of onions for dehydration.

Onion varieties vary materially in yield per acre, drying ratio, sugar content, pungency and colour. Pungent varieties of light colour are preferred.

Jones and Bisson (4) give the following data on the percentage of dry matter of eight varieties of onions.

Variety	Per cent. dry matter
Sweet Spanish	5.50
Grano	7.16
Italian Red	8.83
California Early Red	9.63
Southport White Globe	10.78
Ebenezer	11.17
White Portugal	11.24
Australian Brown	12.10

The drying ratio differs considerably according to the varieties. Crusss and Mackinney (3) found the following drying ratios for several varieties of onions: Stockton Yellow Globe, ranging from 10.5 : 1 to 11.5 : 1; California Early Red, 9.8 : 1 to 10.6 : 1; Grano 10.9 : 1 to 11.7:1, San Joaquin, 13.6 : 1 to 13.7 : 1, Southport White Globe, 8.4 : 1 and Australian Brown 7.1 : 1 to 6.9 : 1.

Preparation for drying:

The principal operation in the preparation of vegetables for drying are (1) washing; (2) sorting; (3) trimming; (4) peeling (roots and tubers only); (5) sub-dividing; (6) blanching; and (7) loading on trays.

Onions present a difficult problem. The outer paperlike husks must be removed. Some operators remove the husks

mechanically by air suction after drying. Some operators remove them by hand, a costly procedure (Cruess 25).

Onions are not blanched as their flavour is better unblanched - Cruess and Mackinney (3). According to Stephenson (5) a blanched dehydrated onion is of little value as a flavouring material.

Rate of removing moisture at different stages of dehydration:

While the vegetable undergoing drying is high in moisture content, the rate of moisture loss is high; but at a low moisture content, the rate becomes very slow. Sugihara and Cruess (6) dehydrated blanched string beans at 150°F. In the first 15 minutes the beans lost 45 per cent of their moisture, in the fifth 15 minutes, 6 per cent., in the tenth, only 1 per cent. In the first 2 hours only 18 per cent, in the third 2 hours 3.2 per cent. It required additional 2 hours to remove the next 1 per cent. and to bring the final moisture to about 4 per cent.

Effect of air velocity on drying rate:

The velocity of air in a given tunnel determines the volume of air per minute. The greater the velocity, the more rapid the rate of drying. In experiments made by Christie and Matsumoto (7) the effect of air velocity on the length of

time required to dry carrots, cabbage and peas was found as shown in table (1).

TABLE (1) EFFECT OF AIR VELOCITY ON LENGTH OF TIME NEEDED TO DRY CARROTS, CABBAGE AND PEAS

Air velocity in linear feet per minute	Time required to dry		
	Carrots	Cabbage	Peas
	hours	hours	hours
250	5.3	5.5	4.7
500	4.0	4.0	3.3
750	3.5	3.5	2.6
1,000	3.0	3.2	2.0

Effect of heat:

Near the end of the drying period any vegetable becomes susceptible to heat damage. Making observations on colour, odour and flavour after 6 to 8 hours heating Cruess and Mackinney (3) found that cabbage showed slight but definite injury at 140°F. with 8 to 10 per cent. relative humidity, and pronounced injury at 30 per cent. Carrots showed no appreciable injury even at 160° F. and 30 per cent relative humidity.

Potatoes showed slight injury at 160°F. at a humidity of 8 to 10 per cent. and at 155°F. and 30 per cent. Onions showed marked injury in colour and odour at all temperatures used and both humidities. Cruess and Mackinney (3) considered that dehydration of onions should be carried to less than 4 per cent. moisture, finishing at not above 135°F., after drying onions are usually packed in air, though their colour and flavour are better retained in vacuum or inert gas.

The Effect of dehydration on ascorbic acid:

Ascorbic acid is sensitive to atmospheric oxidation. It was reported by Cruess and Mackinney (3) that a shorter drying time at 150°F to 160°F, is less destructive to vitamin C than a longer period at 120°F. As Cruess and Joslyn (8) have shown, the loss of ascorbic acid in drying is largely nonenzymatic.

The data in the literature are rather contradictory concerning the losses of ascorbic acid. The destruction of ascorbic acid is catalyzed by oxidising enzymes. Some vegetables are high in these oxidizing enzymes, e.g. cabbage and squash, and consequently difficult to dehydrate without marked loss in ascorbic acid. Others e.g. spinach, are relatively low in these enzymes and so should be comparatively easy to dehydrate without a great loss pf ascorbic acid. Tressler (9).

Ascorbic acid is especially sensitive to oxidation, particularly in alkaline or nearly neutral solutions. Tressler, Mack and King (10) and Tressler (11) reported that vegetables other than rhubarb, tomatoes, cabbage and root crops, rapidly lose vitamin C, when stored at room temperature or higher. Certain enzymes and copper salts catalize its oxidation which occurs rapidly at a pH of 5 or higher. For this reason, non acid vegetables lose vitamin C more rapidly during dehydration than do fruits which are relatively more acidic.

King and Tressler (12) stated that vegetables dried according to common home and commercial practice are practically devoid of vitamin C because of enzymic oxidation. Special precautions may be taken, however, to prevent much of the loss. Sulphite treatment, according to Morgan (13), and drying in vacuo (both) afford a measurable degree of protection. Delf and Skelton (14) reported that the antiscorbutic factor was almost completely destroyed during slow dehydration of cabbage. Some of the dehydrated cabbage samples prepared by Delf and Skelton were scalded prior to dehydration and others were not. In each case dehydration at 37°C caused great destruction of vitamin C. However, the scalded samples retained more than

those not scalded.

According to Givens and McClugage (15) potatoes dehydrated at 55° to 60°C. retained more vitamin C than either the product dehydrated at 35° to 40° or that dehydrated at 75° to 80°C.

A total loss of vitamin C from spinach dehydrated on a laboratory scale was reported by Dunker and Fellers (16). Dutcher (17) has indicated that rapid drying in an inert atmosphere conserves the vitamin C content of spinach. Dehydrated potatoes were reported by Javillier (18) to contain about 20 mg. per 100 grams and that of untreated potatoes containing 70 per cent water 6 mg. per 100 grams.

Studying the retention of ascorbic acid in vegetables during dehydration, Mathiesen, Jakobsen and Kvalhein (19) and Mathiesen, Jakobsen and Solvig (20) concluded that commercial products were found to retain from 2 to 50 per cent of their original vitamin C content. Very carefully dehydrated products which had not been heated above 70°C contained 50 to 82 per cent of the original vitamin C value.

Givens and McClugage (21) found that tomatoes lost two thirds of its ascorbic acid content during dehydration.

Chiye Ashikaga (22) reported that drying destroyed 60 to 80 per cent of vitamin C of onions. According to Sisakyan

(23) the vitamin C content of vegetables falls sharply during ordinary drying. Davis, Eidt, McArthur and Strachan (24) concluded that losses of vitmin C in potatoes vary from 11.5 to 55.7 per cent during the time involved in the total procedure of processing and packing with immediate subsequent analysis.

THE VOLATILE SULPHUR CONTENT OF THE ONIONS

It is generally known that onions and members of the genus Allium owe their pungency and particular taste to an essential oil that is specific for each species. The volatile oil of Allium cepa L. was first investigated by Semmler (26) in 1892. He demonstrated the extremely high degree of pungency by showing that this oil occurs in ~~tons~~ onions in a concentration of only about 0.005 per cent. After distilling 5000 Kg of onions he was able to obtain only 233 g. of crude oil. Determining some of the physical constants and the chemical composition of the crude oil, Semmler showed that the principal constituent of oil is allyl-propyl-disulphide

$$C_3 H_7 - S$$
$$|$$
$$C_3 H_5 - S$$

The crude oil was found to contain 43.37 per cent. sulphur, while the sulphur content of pure allyl-propyl-disulphide is 43.26 per cent. Although Semmler studied some of the chemical properties of onion oil he did not develop any analytical procedure by which the oil could be measured quantitatively.

Peterson (27) proposed a method for determining the volatile sulphur in plants. According to this method a stream of air is passed through a wide U tube containing the plant tissue and heated to 100°C. The volatile sulphur being drawn through and absorbed by copper oxide filings. The copper sulphate formed was dissolved in water and the sulphur determined as barium sulphate. Distillation of volatile sulphur compounds into standard ammonical silver nitrate solution to form silver sulphide, with back titration of the residual silver with potassium thiocynate, has been employed in several modifications to determine the volatile sulphur content of plants, Gros and Pichon (28) and Schuphan (29).

Platinius (30) proposed a method designed especially for onions. It involves acid hydrolysis, distillation into saturated bromine water, and determination of volatile sulphur as barium sulphate. A period of three days is required to complete an analysis. Valuable studies in

relation to pungency of onions have been made by its use - Arasimovich and Ivanova (31) and Platenius and Knott (32,33,34) Eaton (35) employed it in measuring the volatile sulphur content of black mustard plants.

The methylene blue method, involving Caro's reaction, has been used for hydrogen sulphide in solution by Fredenberg and Münch (36), Heath and Lee (37), Pomeroy (38) and by Suslova (39): in proteins by Sheppard and Hudson (40); in sugar by Ambler (41); in meat and fish by Almy (42) and Diemair, Strohecker and Keller (43); in ~~faeces~~ faeces by Lorant and Reimann (44); for sulphur in iron and steel by Lindsay (45) and Mecklenburg and Rosenkränzer (46) and for cystine by Toyda (47) and Vassel (48). Currier (49) employed it for the determination of volatile sulphur in onions.

The method is based on the reaction between p-amino dimethylaniline hydrochloride and H_2S in the presence of ferric ammonium sulphate to give methylene blue.

Several investigators have shown that flavour formation in onion and garlic is an enzyme reaction. Cavallito, Baily and Buch (50) prepared an odourless powdered garlic by destroying the enzyme before any cleavage of the precursor could occur. Cavallito and Baily (51) succeeded in isolating from garlic an oily substance which they named Allicin. Besides possessing the typical odour of garlic Allicin exerts

a marked antibacterial action. It was synthesized by Stoll and Seebeck in 1947 (52). The same authors (52) (53) isolated a sulphur containing but odourless compound which they called Alliin ~~Allini~~ and was synthesized in 1951 (54). On treatment with the specific enzyme Allinase, also found in garlic, Alliin ~~Allini~~ decomposes into Allicin, pyruvic acid and ammonia (Stoll and Seebeck (55). The reaction between Alliin ~~Allini~~ and Allinase takes place very rapidly, the optimum pH being between 5 and 8, the optimum temperature at 37°C, as for most other enzymes.

Kohman's work (56) traces the short life history of the lachrymating factor. All evidence indicates that the enzyme and prucursor cells are separate in the onion bulb or garlic - clove. Flavour can be obtained only after the connecting cell walls have been ruptured under favourable pH and temperature conditions. When an onion is sliced, there is a rupturing of cells only at the cut surface. The lachrymator and sulphur-bearing flavouring compounds are formed by cleavage of the prucursor by the enzyme (Stephenson (5)).

Platenius (30) made the assumption that pungency is proportional to the volatile sulphur content of the onion. He found that onions differed 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.

FACTORS AFFECTING THE PUNGENCY OF ONIONS

Relative pungency of different onion varieties:

Platenius and Knott (34) reported that the different varieties of onions differed considerably in their volatile sulphur content. Some varieties were found to contain twice as much volatile sulphur as other varieties. The same authors (32) concluded that varieties of onions can be grouped into several classes according to their volatile sulphur content. A, is the distinctly mild onion, B those which are intermediate in pungency and under C are the varieties which are decidedly strong.

Although onions were grown in widely separated locations differences in pungency as a result of ecological conditions were relatively small, though fairly consistent.

From the study of the moisture content of different varieties of onions Jones and Bisson (47) drew the following conclusion: that those varieties which 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. This view was supported to some extent by Platenius and Knott (34) although there were several notable exceptions, the strongest and mildest variety both had a water content of 90 per cent. This inverse relationship of pungency and water was reported by Eaton (35) in black mustard plants, where the tissue with the higher water content has also the lower fresh weight percentage of volatile sulphur. The dry weight percentage showed a similar but smaller difference, indicating that the decreased pungency of the tissue of higher water content is not due entirely to a dilution of the volatile sulphur with water, but there is actually less volatile sulphur in proportion to the remainder of the dry matter.

EFFECT OF ENVIRONMENTAL FACTORS ON ONION PUNGENCY

Temperature:

It was found by Platenius and Knott (34) that temperature had a striking effect on the volatile sulphur content, and that onions grown at a temperature from 70° to 80° were three times

as pungent as those grown at 50° to 60°.

Water Supply:

Irrigated onions had a volatile sulphur content lower than those not irrigated, and the bulbs of the irrigated ones were bigger than the non-irrigated. Platenius and Knott (34).

Soil types and watersupply.

The effect of the different types of soils on the volatile sulphur content of the onion was reported by Platenius and Knott (34) who grew a variety of onion in three different types of soil - peat, sandy loam and sandy soils with a low and high water table for each experiment. Onions grown in peat soil were found to contain the highest amount of volatile sulphur while those grown in sandy soil were the lowest. In all the experiments the bulbs grown at a high water level were bigger and contained less volatile sulphur than those grown at a low water level.

A striking correlation was found by Platenius and Knott (34) between the volatile sulphur content of the onion and the soils on which they were grown. Whereas the sandy loam contained 10 times and the peat 100 times as much sulphur as the sandy soil, the corresponding volatile sulphur content of the onions was only 25 and 58 per cent higher on the sandy loam and peat than it was on the sandy soil. The addition

of an equivalent of 600 pounds of sodium sulphate per acre to the sandy soil doubled the percentage of sulphur present but was insufficient to have an appreciable effect on the pungency of the onions. Eaton (35) reported that black mustard plants grown in minus-sulphur nutrient solutions the leaves tasted flat, as compared with the sharp acrid taste of plus sulphur leaves. Analysis showed that the minus sulphur leaves were almost completely lacking in volatile sulphur. He also found that the leaves of plants grown in sand with a complete nutrient solution contained more volatile sulphur than those grown in soil.

Effect of stages of maturity.

The effect of the stages of maturity on the volatile sulphur content of the onion was reported by Platenius and Knott (33) who grew three varieties of onions and found that the volatile sulphur increased till the plants approached maturity and the peaks of the curves were reached just before the tops began to fall over. Eaton (35) found that the age of the leaves of black mustard plant affects their volatile sulphur content, where the upper leaves were much more pingent than the lower ones. A similar difference but less magnitude appeared when the leaves of young plants were compared with those of the older ones. The younger the plant the more volatile sulphur was found in its leaves.

Effect of storage.

The changes in the volatile sulphur during storage was reported by Platenius and Knott (34) who stored two varieties of onions in 1936 and 1937 at 33°F. The volatile sulphur content increased as the storage period progressed. However, the increase appeared to proceed at a slower rate towards the end of the storage period, in fact one of the varieties stored in 1937-1938 showed a slight decrease in its content of volatile sulphur. He attributed the variations in the volatile sulphur content of the different samples partly to shrinkage losses and changes in the percentage of dry matter. He stated that these two factors alone cannot account for the general tendency of the volatile sulphur to increase during the storage period. Instead, it is evident that some of the onion oil was formed during storage from other forms of sulphur and organic constituents in the bulbs.

ASCORBIC ACID CONTENT OF THE ONION

The factors that influence the amount of ascorbic acid in fruit and vegetables are receiving increasing attention. Investigations into the difference between members of different plant families and genera, between different species of the same genus, between different varieties of the same species,

between different parts of the same plant, between the same part at different stages of development are typical of one kind of inquiry; in addition attention is being turned to the effects of different types of fertilizers and general conditions of cultivation on the nutrient make-up of the crop.

Although onions have been reported as being a rich source of vitamin C, Sherman (57), the published values range from 0.05 to 0.15 mg per g. Olliver (58), Fujita and Ebihara (59), Mayfield and Richardson (60), and Chi and Read (61). Murphy (62) reported that ascorbic acid of different varieties of onions ranged from 0.4 to 0.17 mg per g. Werner (63) in studying the ascorbic acid content of different varieties of Nebraska potatoes, found that some varieties were superior to others.

The uneven distribution of ascorbic acid has been reported in many vegetables and fruits. It has been shown that the skin of the mature apple contains much larger amounts of vitamin C than does the central position, Bracewell, Kidd, West and Zilva (64) and Birch, Harris, and Ray (65). The outer leaves of the onion bulb were found to contain much less ascorbic acid than the central leaves, Murphy (62) McHenry and Graham (66) reported an analogous phenomenon in turnips and suggested that vitamin C production is perhaps dependent upon the photosynthetic process in the leaves and that is transported thence to the root.

Ascorbic acid was reported by several workers to be affected by the stage of maturity of the plant. As the onion approaches and reaches maturity its ascorbic acid value falls - Murphy (62). According to Becker (67) spring onions contain a much higher percentage of vitamin C than the mature onions. Zilva and Kidd (68) found that as apple fruit approaches maturity the proportion of ascorbic acid increases. Rubin (69) concluded that ascorbic acid is formed in the green assimilating parts of the plants.

Plants not containing chlorophyll do not form ascorbic acid. Plants growing in the sunlight have more ascorbic acid than those grown in the shade - Devytinin (70).

Shapiro (71,72) reported that peat-type soils reduce the vitamin C content of potatoes in comparison with loamy soils. According to Naik, Shah and Pandya (73), the Vitamin C of vegetables depends largely on the amount of nitrogen applied. Phosphoric fertilisers have little effect. Aslanyan and Vartanyan (74) concluded that nitrogen fertiliser alone decreases the ascorbic acid content of the tuber of potatoes and the harmful effect of the nitrogen fertilizer can be overcome by the addition of superphosphate.

Results obtained by Wokes and Organ (75) suggested that the vitamin C content of tomatoes grown in Great Britain is

affected by the degree of exposure to sunshine during cultivation. It is also related to the size of the fruit, position of the plant, date of collection. These suggestions have been supported by Pollard, Kieser and Bryan (76, 77), who found the average vitamin C content of tomatoes grown outdoors in 1945 was only three quarters of that of tomatoes grown under the same conditions in 1944. The lower vitamin C content in 1945 was correlated with a smaller number of hours of sunshine during August, September and October. Wokes, Barr, Burnskill and Shaw (78) stated, that although some evidence indicated that lower vitamin C content is a result of less exposure to sunshine and lower temperature, the data do not prove those factors to be solely responsible for the variations noted.

Effect of storage on the ascorbic acid.

Chapell (79) tested Brussels sprouts stored at room temperature on seven successive days after purchase and concluded there was a definite and fairly steady fall in vitamin C concentration as storage proceeded. Rapid loss of vitamin C from some vegetables stored at room temperature and slower loss during storage at 32°F. was reported by Olliver (58) for example at room temperature spinach lost 78 per cent of its original vitamin C content in two days and asparagus tops 80 per

cent in 4 days. The same author (80) states that as a general rule, the majority of green leafy vegetables lose 10 per cent of their initial vitamin C for each day's elapse after harvesting, whereas root vegetables lose vitamin C at a slower rate.

A table summarizing the effect of storage on the ascorbic acid of raw foodstuffs mostly vegetables, has been compiled by Marston and Dawbarn (81). They quote from published work, Gould, Tressler and King (82), Mack, Taply and King (83), Tressler, Mack and King (10) and Wheeler, Tressler and King (84), results which demonstrate that a greater proportion of the original vitamin C is retained during storage at 34-37°F than at 70-73°F. For example, French beans lost 2-34 per cent of their vitamin C after 1 day's storage and 5-50 per cent after 2 days at the lower temperature, compared with 11-45 per cent and 21-65 per cent for corresponding times at 70-75°F., cauliflower showed no loss during storage for 14 days at 34-37°F., but lost 37 per cent of its original vitamin C content in 4 days at room temperature; spinach kept at 34°F lost 3-4 per cent in 3 days and 8-19 per cent in 7 days, but when stored at 73-77°F the losses were 44-51 per cent in 3 days and 94-96 per cent in 7 days.

According to Murphy (62), onion varieties stored for 3 months under home conditions lost 23 to 64 per cent during the first month, during the second month losses ranged from 0 to 54 per cent, during the third month losses were slight for most varieties. The actual amounts for all except two varieties remained practically the same. Mayfield and Richardson (60), have reported that winter storage has no effect on the vitamin C content of onions.

Zepplin and Elvehjem (85), found storage of vegetables in a refrigerator had a marked and favourable effect on the retention of ascorbic acid.

Ajisaka, Numata, Dohi and Okubo (86) reported that in green leaves the vitamin C content greatly diminishes after 3 weeks, and may even completely disappear after 4-7 weeks of storage. On the other hand, in tubers and in fruit the ascorbic acid is well preserved and is very largely retained even after 7-10 weeks storage.

Berezovskaya (87) concluded that storage of potatoes 19 days at 0° gives a 61 per cent higher retention of vitamin C than in similar vegetables stored 16 days at $10-15^{\circ}$. Celery, cabbage, Chinese onions, radish, green turnips, red turnips and sweet potatoes lost 73-93 per cent of their original ascorbic acid content immediately after harvest - Kung and Fang Fwang (88).

THE SUGAR CONTENT OF THE ONION.

The onion is an old world species which has been cultivated for over 4,000 years. It is said to have been worshipped in Egypt prior to the Christian era. Today the onion is recognised as most important of the food plants in which the food is stored in the bulb - Hill (89). There appears to be little information in the literature regarding the nature and content of their carbohydrates which are probably the constituents of greatest potential significance.

Bennett (90) determined the soluble sugars in the Ebenezer onion and found it to contain 64.23 per cent soluble sugars, 11.34 per cent reducing sugars and 52.89 per cent non reducing sugars and that the ratio of the non reducing sugars to the reducing sugars is a variable in which is influenced by cultural conditions, length of storage and condition of storage. Sheratt (91) reported that onions appear to contain 6 to 9 per cent sugars (fresh weight).

Bennett (90) investigated the nature of the reducing sugars in onions and reported that 69 per cent of the sugars present were of the ketose form and that the aldose and ketose forms were present in Ebenezer onions in the ratio of about one to two. Furthermore, the bulk of the non reducing sugars was found to be sucrose. This fraction when hydrolyzed,

together with the reducing sugars may yield a mixture which constitutes nearly 65 per cent of the dry matter, nearly all of which may be fermented, and which appears to be approximately two thirds d-fructose. Srinivasan, Bhatia and Satyanarayana (92) identified the carbohydrates of onion as fructose, glucose, sucrose and fructosans. Sucrose : monose ratio varies from 0.1 to 21.3 for different varieties of onions. The sucrose content of the bulb is greatest and the leaves lowest, at maturity. A rise in the general sugar content in the bulb is connected with an increase, both absolute and relative in the amount of sucrose - Rubin (93) and (94). Bennett (95) studied the chemical changes in the onion during normal growth. The reducing and non reducing sugars in the tops were found to continue to increase until about the 66th day at which the necks of the tops began to soften. From this point on the sugars are transported to the bulb to the point of depletion. On the other hand, the reducing and non reducing sugars continued to increase in the bulb throughout the growth.

Since sugars are the chief source of energy in respiration, this group of compounds should show the effect of unfavourable conditions of storage. Bennett (96) studied the effect of different storage conditions on the sugar content of Ebenezer onions. The results showed that the

loss of total sugars varied from none to about 8 per cent and that the percentage loss was lowest for cold storage. The non reducing sugars decreased throughout the storage period of 3-5 months, while considerable increase in the reducing sugars occurred. The largest percentage of reducing sugars was found in cold storage. Foskett and Peterson (97) concluded that varieties and hybrids of onions having high percentage of dry matter had a lesser tendency to sprout during storage.

Scupin (98) found, after a great number of analyses covering a period of 8-9 months, that the total sugars and disaccharides content show from the start of storage to the middle of the storage a definite decrease and an increase thereafter. For the monosaccharides there is an increase from the beginning until the end of storage, and an increase of 43 per cent of the initial amount is reached at the end of the storage period. The course of changes in the content of disaccharides was generally equal to the changes in the content of total sugars. The increase in the content of the monosaccharides is generally higher in cold storage.

According to Kapur, Mathur and Singh (99), the percentage of both sucrose and reducing sugars decreased during the course of storage. The greatest decrease in the percentage of sugars

occurred at 46-50°F. The greater the percentage of rooting and germination the greater the losses of sucrose and reducing sugars during storage. In storage trials at 32°, 40° and 50°F with controlled relative humidity varying from 65 to 90 per cent - Wright, Lauritzen and Whiteman (100) - have shown that the sprouting of onions is only slightly influenced by humidity but rather definitely by temperature. According to - Platenius, Jamison and Thompson (101) - experimental lots of onions have remained in perfect condition at 30-32 F., even when the relative humidity was as high as 94 per cent. Jones and Bisson (4) found that varieties of onions of relatively poor storage quality have the highest moisture content, whereas those that keep best in storage have the lowest moisture content.

CHAPTER II

INTRODUCTION

Dehydration, desiccation or drying as applied to foods may be defined as the process of removing surplus water without destruction of cellular tissues, or impairment of energy values. Practically all foods except the ripe seeds of cereals, legumes and few other food plants contain a high percentage of water, and as a result have poor keeping qualities unless conserved by special means. The rapid, regulated drying of such foods gives a product suitable for easy storage and transport.

The general advantages of the dehydration of vegetables may be summarized as follows :-

1. Possibility of utilizing much food now wasted owing to low prices at time of production or difficulty of marketing;

2. Dehydration plants can be located at centres of production and dehydration carried on while the food material is in prime condition;

3. Saving cost of transport in dehydrated form due to less weight and bulk;

4. Increased keeping quality;

5. Nutritional values are conserved;

6. No loss by crushing or spoilage;

7. Saving in cold storage charges;

8. Saving in tonnage for overseas shipment;

9. Foods require only soaking before cooking;

10. Surplus of one season or locality made available at another time or place.

Onions are dehydrated as flakes and as powder. The pungency of the dried product is the most important factor deciding its quality, as they are used commercially in flavouring meat products, canned soups, and other food products. The vast amount of literature on this subject deals mainly with the effect of dehydration on the nutritive value, with little information about its effect on the pungency of the onion. For most vegetables, blanching is the chief step in preparation for drying. The onion is one of the few vegetables not to be blanched, as the blanched product is of little value as a flavouring material (3,5).

With this in view the present investigation was planned to study the effect of varying temperatures and air velocities during dehydration on the volatile sulphur content of the onion.

Such conditions, likely to affect the ascorbic acid and sugar contents of the onion, are also examined.

Volatile sulphur, ascorbic acid, and sugar content of English, French and Egyptian varieties imported from France and Egypt and the changes of these components during growth and storage are studied.

The arrangement of the text is as follows. In Chapter (III) the effect of various temperatures and air velocities on the drying rate, volatile sulphur, ascorbic acid and sugar content in onions are studied. Chapter (V) shows the changes in the volatile sulphur content of the different varieties during growth and storage. The changes in the ascorbic acid and sugar contents during growth and storage are shown in Chapters (VI) and (VII).

C H A P T E R III

THE DEHYDRATION OF ONIONS

The experiment was designed to study the effect of air velocity and temperature on the dehydration of onions.

The dehydrater, designed in the laboratory, was provided with an electric heater adjustable to ± 1°C. For the study of the effect of the different temperatures, it was necessary to use a wide range, between the maximum and the minimum, so that the most favourable conditions for dehydrating onions could be observed. The temperatures used were a minimum of 50°C and a maximum of 75°C. By raising the temperature 5°C six different temperatures were used which were 50°, 55°, 60°, 65°, 70° and 75°C.

The dehydrater had a forced air draught with a maximum air velocity of 1400 f.p.m., but the air velocity could be controlled to give a minimum of 400 f.p.m. The various air velocities used in the experiments were 400, 650, 900, 1150 and 1400 f.p.m.

The onion variety used throughout the experiment was "Best of all". The thickness of the slices was $\frac{1}{8}$" and the

tray load was ½ lb./sq.foot which was applied to all the drying experiments. The only variations were the temperatures and the air velocity.

The effect of the air velocity and the temperature, on the drying rate of the onion, was observed by weighing the trays every hour and the loss in weight was recorded. After the samples had been dried they were packed in well sealed bottles and used to study the effect of the varying drying conditions on the volatile sulphur, ascorbic acid and sugar content of the onion.

RESULTS AND DISCUSSION

EFFECT OF THE VARIOUS TEMPERATURES ON THE DRYING RATE OF THE ONION

Table (2) Fig. (1) shows the effect of the different temperatures on the drying rate of the onions. At different temperatures and any given air velocity it can be seen that the higher the temperature the shorter the time required for drying.

The effect of the varying temperatures, at any given air velocity, can best be presented by the percentage loss of the weight of the sample during the period of dehydration.

TABLE (2) THE EFFECT OF THE VARIOUS TEMPERATURES AND AIR VELOCITIES ON THE DRYING RATE OF ONION.

Air Velocity	400 f.p.m.						650 f.p.m.						900 f.p.m.						1150 f.p.m.						1400 f.p.m.					
Temp.	50°	55°	60°	65°	70°	75°	50°	55°	60°	65°	70°	75°	50°	55°	60°	65°	70°	75°	50°	55°	60°	65°	70°	75°	50°	55°	60°	65°	70°	75°
Time in hours	Weight in grams*						Weight in grams*						Weight in grams*						Weight in grams*						Weight in grams*					
1	42.5	41.5	40.5	39.7	38.7	37.7	38.5	37.6	36.9	34.6	32.2	30.6	34.1	33.0	31.5	30.5	28.0	25.0	32.9	30.3	27.5	25.9	22.5	21.3	27.5	26.7	25.5	24.9	19.3	16.2
2	32.0	31.5	30.5	29.3	27.5	26.0	26.9	26.0	25.1	22.8	20.3	15.8	22.1	18.3	17.4	15.0	14.3	9.5	19.6	16.9	15.6	13.1	11.6	9.1	17.5	16.0	15.1	12.9	9.3	7.7
3	24.0	22.5	22.0	20.8	17.5	16.7	19.4	17.1	16.3	14.5	10.1	9.5	14.2	11.0	10.5	10.1	9.4	6.4	12.1	9.7	8.8	8.2	7.4	5.9	11.0	9.0	7.6	6.8	5.8	5.2
4	18.4	15.3	13.3	12.3	11.2	10.4	14.1	10.0	9.3	8.3	7.1	6.6	9.5	8.1	7.5	6.9	6.5	5.4	9.2	7.5	6.5	5.8	5.6	5.2	8.5	7.3	6.2	5.8	5.4	5.1
5	12.2	10.4	10.0	9.2	7.6	6.4	9.3	8.2	7.6	6.4	6.0	5.8	8.5	6.9	6.6	6.1	5.7	5.2	8.1	7.1	5.6	5.4	5.4		7.5	6.6	5.7	5.5	5.2	
6	9.8	8.5	7.7	7.1	6.1	5.8	8.2	7.5	6.5	6.0	5.5	5.3	7.6	6.6	5.8	5.6	5.4		7.2	6.4	5.4	5.3			7.1	6.2	5.5	5.2		
7	7.9	7.4	7.2	6.1	5.6	5.3	7.0	6.6	6.0	5.6	5.2		6.4	5.7	5.5	5.3			6.4	5.9	5.3				6.5	5.9	5.4			
8	7.4	7.0	6.5	5.8	5.4		6.6	6.1	5.5	5.4			5.8	5.5	5.3				5.5	5.5					6.2	5.7				
9	7.0	6.3	6.1	5.5	5.3		6.1	5.5	5.3				5.5	5.4					5.4	5.4					5.6	5.4				
10	6.5	6.0	5.5	5.3			5.7	5.2					5.4						5.3						5.4					
11	6.0	5.5	5.3				5.4						5.3																	
12	5.5	5.4					5.4																							
13	5.4	5.3																												
14	5.3																													

* Weight of sample = 50 g.

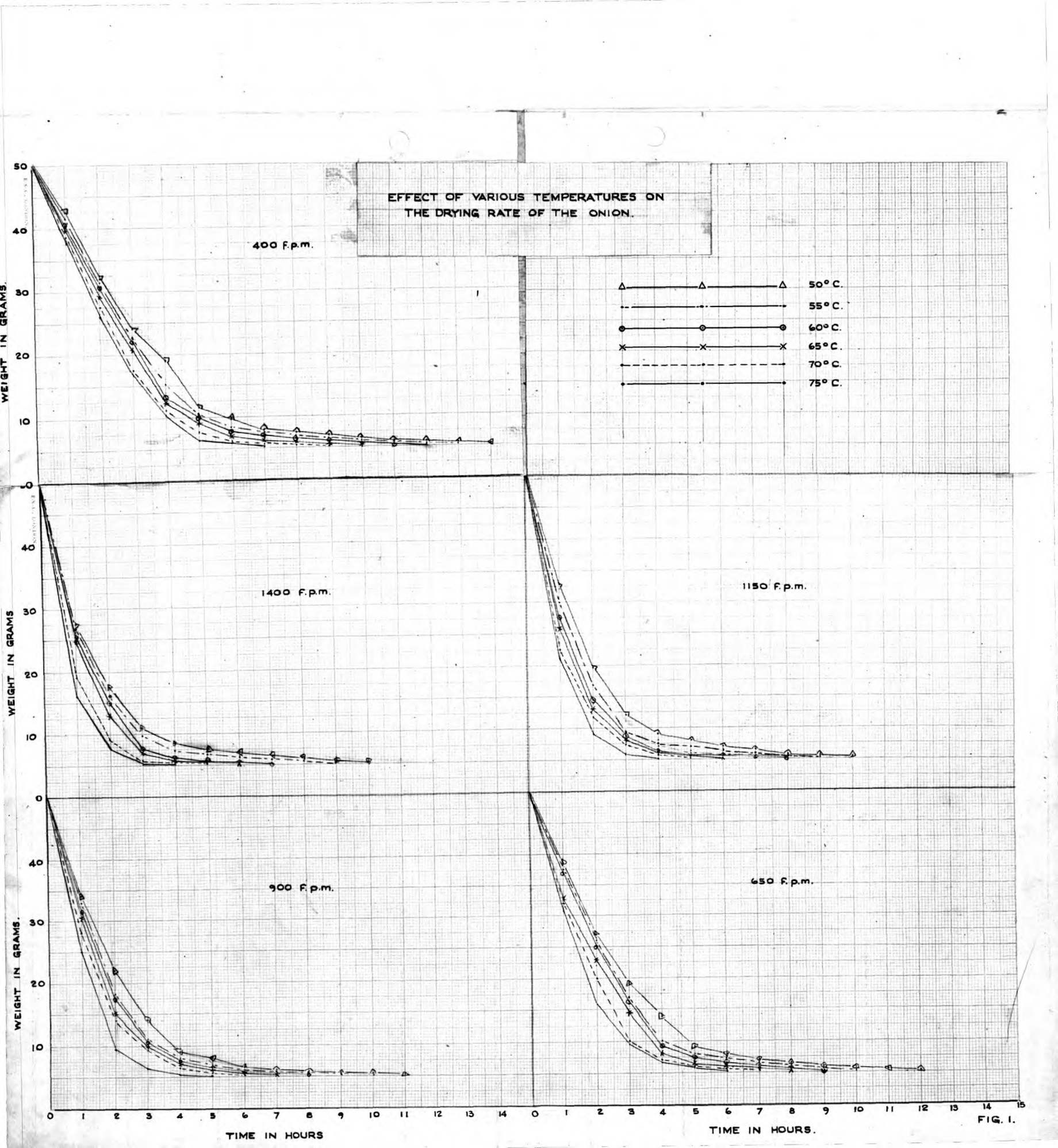

EFFECT OF VARIOUS TEMPERATURES ON
THE DRYING RATE OF THE ONION.
400 F.p.m.
1400 F.p.m.
1150 F.p.m.
900 F.p.m.
650 F.p.m.
50° C.
55° C.
60° C.
65° C.
70° C.
75° C.
WEIGHT IN GRAMS.
TIME IN HOURS
TIME IN HOURS.

FIG. 1.

At any given air velocity the loss in weight of the sample differed considerably according to the temperature used. At an air velocity of 1400 f.p.m. and 75°C the sample lost 67.6 per cent of its weight during the first hour of drying, 52.4 per cent during the second hour, 32.4 per cent during the third and 1.9 per cent during the fourth. Reducing the temperature, the loss in weight at the same air velocity decreased, and the time required for drying increased accordingly.

It is important to note the effect of the various temperatures on the onion itself during dehydration. The onion became very susceptible to heat damage near the end of the drying period. At the earlier stages of drying, when the onion was high in moisture content the effect of heat was much less than in the later stages. From the experiments on the different temperatures and its effect on the onion, the temperatures can be divided into two groups, according to their effect. The first, which includes the high temperatures of 75°, 70° and 65°C and the second group which includes the low ones 60°, 55° and 50°C.

The onions were very much affected by the high temperatures and charring occurred at all high temperatures and at all air velocities. At 70° and 75°C charring occurred

earlier than at 65°C. At the high air velocities, 1400, 1150 and 900 f.p.m. that effect was observed very much earlier than at the lower air velocities 650 and 400 f.p.m. While charring started after 2 hours at 75°C and 70°C at 1400 f.p.m. it started after 4 hours and 6 hours at 400 f.p.m. This indicates that the effect of the heat is very much greater during the later stages when the onions have lost most of the moisture than at the earlier stages when the sample was high in moisture content. Table (3) summarizes the effect of heat on the onion at the higher temperatures and different air velocities, and shows the colour of the dried sample affected by the high temperatures used. The higher the temperature the greater the change of the colour of the final product. It was clearly observed that the samples dried at 75°C had a darker brown colour than those dehydrated at 70° C and 65°C.

The second group, which includes the lower temperatures, had no visible effect on the onion and no charring occurred. When dehydration was carried out at any of these temperatures and at all air velocities, the colour of the final product was unchanged. Although using high temperatures reduced the time required for drying considerably, the final product was very much affected by the heat, which shows that drying

T A B L E (3) THE EFFECT OF HIGH TEMPERATURES ON THE ONION

Time at which charring commenced	Temperature °C	Air Velocity f.p.m.
	75	1400, 1150
After 2 hours	70	1400
	75	900
After 3 hours	70	1150
	65	1400
	75	650, 400
After 4 hours	70	900
	65	1150
	70	650, 400
After 6 hours	65	900
After 7 hours	65	650, 400

onions at such temperatures is not very successful. Using the lower temperatures, on the other hand, prolonged the time required for drying but the final samples were not affected which indicates that dehydrating the onion at 60°, 55° and 50°C was much more successful. Considering the lower temperatures, it appears that dehydrating at 60° besides showing no damage to the onion has the advantage of a shorter drying time than dehydrating at temperatures 55° and 50°C.

THE EFFECT OF AIR VELOCITY ON THE DRYING RATE OF THE ONION.

The results of the effect on the drying rate of the onions are shown in table (2) and illustrated in Fig. (2). It can be seen that the greater the air velocity the more rapid the drying rate of the onion. The greater effect of the air velocities can be noticed during the initial stages of dehydration when the sample contains a high moisture content. Near the end of the drying period the variation in the drying rate was not so great. The flowing air carries to the product the heat units required for vaporizing the moisture and removes the resulting moisture vapour. In the initial stages of drying, the surface of the product is moist and the transfer of moisture from the

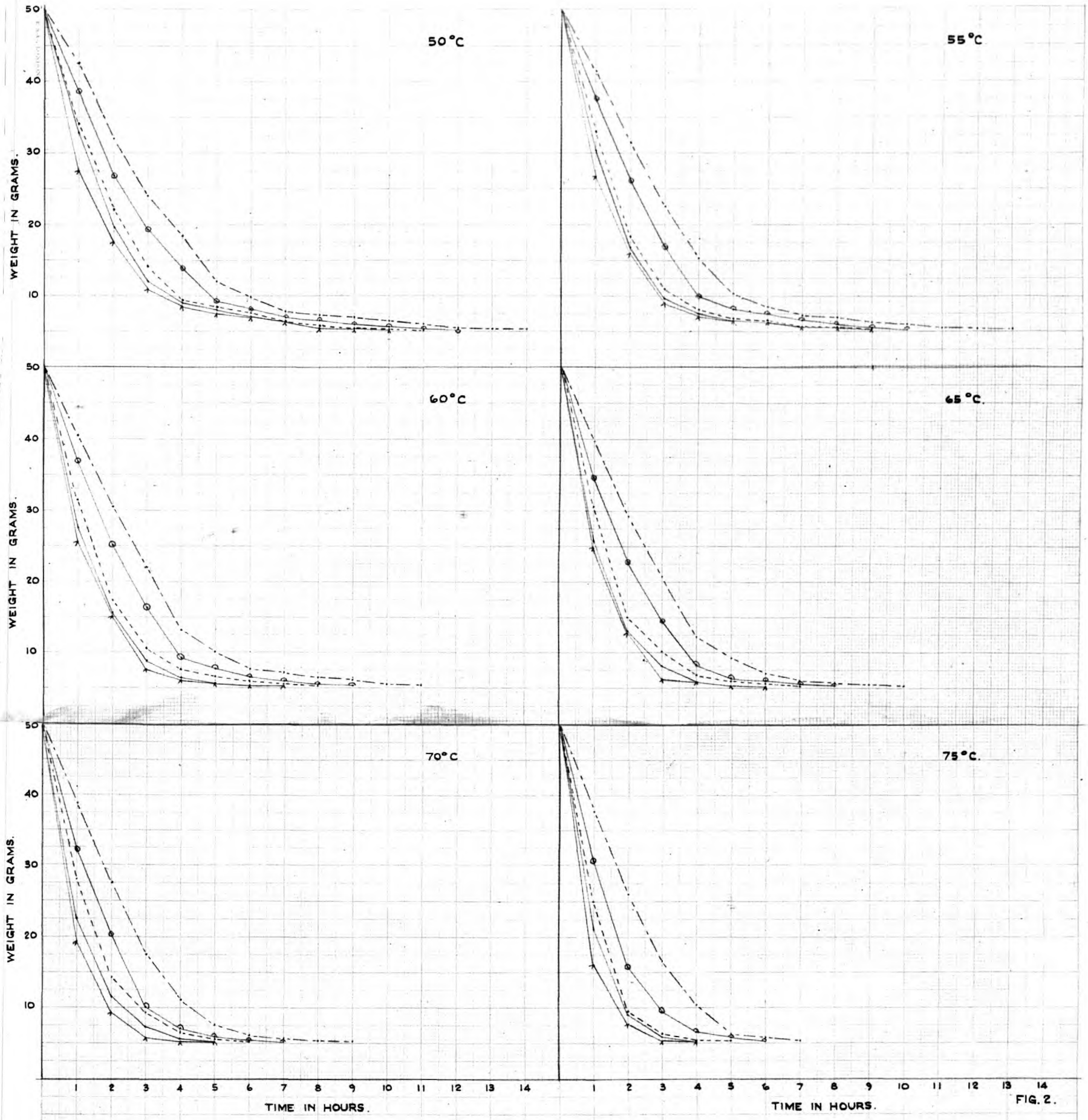


FIG. 2.

EFFECT OF VARIOUS TEMPERATURES AND AIR VELOCITIES ON THE DRYING RATE OF THE ONION.

tissue to the surface keeps pace with evaporation from the surface. Near the end of the drying period moisture diffusion is slow, lagging far behind the ability of the hot air to evaporate and remove the moisture. The rate of removing the moisture, at various air velocities at any given temperature, is much more pronounced than that of the various temperatures and any given air velocity. By doubling the air velocity the drying period was appreciably reduced but not proportionately because the rate of diffusion of moisture to the surface in the almost dried sample becomes an important factor. From the table and the curves it can be seen that onions dehydrated at 60° and 400 f.p.m. needed eleven hours for drying, while samples dried at the same temperature and 900 f.p.m. required eight hours.

In considering the combined effect of the varying temperatures and air velocities it was noted that the higher the temperature and air velocity, the shorter the time needed for drying. Since the effect of higher temperatures and air velocities had a damaging effect on the onion, it appears that dehydration at lower temperatures and higher air velocities had the advantages of not damaging the onions and a reasonable drying time. Onions dehydrated at 60°C and 1150 and 1400 f.p.m. required seven hours for

drying which is much shorter than dehydrating at 50° and 55°C with the same air velocities.

THE EFFECT OF DEHYDRATION ON THE VOLATILE SULPHUR CONTENT OF ONIONS

THE EFFECT OF DIFFERENT TEMPERATURES:

The results for the volatile sulphur content of the different onion samples dehydrated at different temperatures are shown in Table (5). Fig. (3) illustrates the effect of the various temperatures and air velocities. From the table and the curves it can be seen that the temperatures had a varying effect on the volatile sulphur. All samples showed a considerable loss in their volatile sulphur content.

According to the effect of the temperatures and the amount of volatile sulphur lost during dehydration, the various temperatures used can be divided into two groups.

The first group which had the greater effect on the volatile sulphur includes the temperatures 50°, 70° and 75°C.

The second group of temperatures at which the onion samples showed lower losses in comparison with the previous group includes the temperatures 55°, 60° and 65°C. It is noticeable that the greatest losses occurred when dehydrating onions at 50°, 70° and 75°C. at all air velocities. At 50°C

T A B L E (5) VOLATILE SULPHUR CONTENT OF ONIONS DEHYDRATED AT VARIOUS TEMPERATURES AND AIR VELOCITIES

Air Velocity f.p.m.	Volatile Sulphur content											
	50°C		55°C		60°C		65°C		70°C		75°C	
	ppm	% loss	ppm	% loss	ppm	% loss	ppm	% loss	ppm	% loss	ppm	% loss
400	510	36.6	540	32.5	570	28.8	520	35.0	500	37.5	500	37.5
650	540	32.5	600	25.0	630	21.3	570	28.8	540	32.5	490	38.8
900	600	25.0	690	13.9	710	11.3	580	15.0	620	22.5	600	25.0
1150	580	27.5	610	23.8	680	15.0	610	23.8	600	25.0	590	26.3
1400	590	26.3	630	21.3	700	12.5	640	20.0	620	22.5	610	23.8

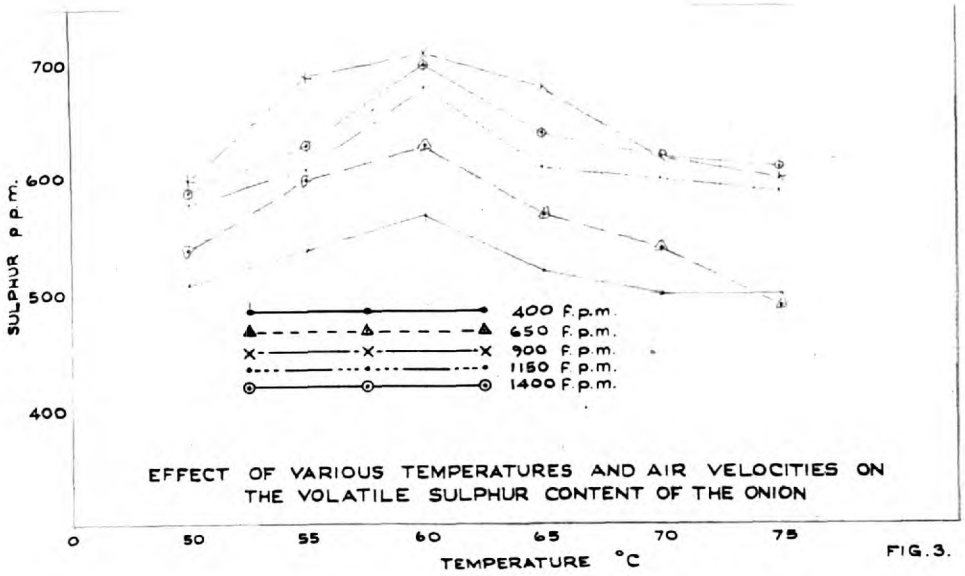

700
600
500
400
SULPHUR p.p.m.
400 F.p.m.
650 F.p.m.
900 F.p.m.
1150 F.p.m.
1400 F.p.m.
EFFECT OF VARIOUS TEMPERATURES AND AIR VELOCITIES ON THE VOLATILE SULPHUR CONTENT OF THE ONION
0
50
55
60
65
70
75
TEMPERATURE °C

FIG. 3.

the onions lost from 25 to 36.6 per cent of their volatile sulphur, at 70°C the losses ranged from 22.5 to 37.5 per cent and, at 75°C the losses were from 23.8 to 38.8 per cent. It is interesting to note that in this group, the temperatures are the lowest and highest used.

In the second group of temperatures, onions lost rather a lower percentage of volatile sulphur than the previous group. The highest values for volatile sulphur were obtained when dehydrating the onion at 60°C. At all air velocities it is outstanding that at 60°C the lowest losses occurred in the volatile sulphur content of the onion. At 400 f.p.m. the percentage loss was 28.8 per cent, at 650 f.p.m. 21.3 per cent, at 900 f.p.m. 11.3 per cent, at 1150 f.p.m. 15 per cent and at 1400 f.p.m. 12.5 per cent. Dehydrating the onion at 55° and 65°C showed higher losses in the volatile sulphur content than those dehydrated at 60°C, but much higher values than onions dehydrated at 50°, 70° and 75°C. The percentage loss ranged from 13.8 to 32.5 per cent for onions dehydrated at 55°C and from 15 to 35 per cent for those dehydrated at 65°C. It is obvious, however, that the most favourable temperature for dehydrating onions with the least possible loss in volatile sulphur content seems to be at 60°C which showed higher values than the other temperatures used at all air velocities.

THE EFFECT OF AIR VELOCITIES:

The results of volatile sulphur content of onions dehydrated at various air velocities are in table (5). From the results in the table and Fig. (3) it is noticeable that the air velocities had a considerable effect on the volatile sulphur content. The loss in volatile sulphur differed remarkably according to the air velocity used in dehydrating the onion. It is apparent from Fig. (3) that the lower air velocities 400 and 650 f.p.m. had the greatest effect on the volatile sulphur while the higher air velocities had a lesser effect.

Using an air velocity of 400 f.p.m. for dehydration had the greatest effect on the volatile sulphur. At such an air velocity the percentage loss ranged from 28.8 to 37.5 per cent. Onions dehydrated at an air velocity of 650 f.p.m. showed much higher values for the volatile sulphur than those dehydrated at 400 f.p.m. where the percentage loss ranged from 21.3 to 38.8 per cent.

Higher air velocities had less effect on the volatile sulphur content of the onion than the lower air velocities. Raising the air velocity to 900 f.p.m. showed higher values for the volatile sulphur but with still higher velocities (1150 and 1400 f.p.m.) the values decreased again.

In other words the loss in the volatile sulphur content of onions dehydrated at 900 f.p.m. and all temperatures was at a minimum where the percentage loss ranged from 25 to 11.3 per cent.

Dehydrating at 1150 f.p.m. showed higher losses than dehydrating at 900 and 1400 f.p.m. at all temperatures where the percentage loss ranged from 15 to 27.5 per cent. Dehydrating the onion at 1400 f.p.m. showed higher losses than those at 900 f.p.m. but less than those at 1150 f.p.m. The percentage loss for samples dehydrated at 1400 f.p.m. was from 26.3 to 12.5 per cent.

From these results it appears that using high air velocities in dehydrating onions was most favourable in minimizing the loss in volatile sulphur while dehydrating at air velocities lower than 900 f.p.m. increased the losses considerably.

THE EFFECT OF DEHYDRATION ON THE VOLATILE SULPHUR CONTENT OF VARIOUS VARIETIES OF ONIONS:

English, French and Egyptian varieties were dehydrated at 60°C and 1400 f.p.m. during the two seasons of 1951 and 1952 and their volatile sulphur content estimated.

The results for the season 1951 are summarized in table (6). It indicates that all varieties lost a considerable

TABLE (6) EFFECT OF DEHYDRATION ON THE VOLATILE SULPHUR CONTENT OF DIFFERENT VARIETIES OF ONIONS (1951

Variety	Volatile Sulphur Content		Amount lost during drying	
	Fresh Samples	Dried Samples		
English Varieties:	p.p.m.	p.p.m.	p.p.m.	per cent
Alisa Craig 1	610	460	150	24.6
Southport Yellow Globe	701	370	331	47.3
Up to Date	719	650	69	9.6
Best of All	558	385	173	31.1
White Spanish	766	475	291	36.1
Giant Zittau 1	743	380	363	48.9
Giant Zittau 2	865	510	355	41.1
Bedfordshire Champion	790	640	150	19.1
Red Zittau	688	600	88	12.9
Dahneils Red Globe	615	410	205	33.4
Cambridge 10	830	530	300	36.1
Alisa Craig	1007	550	547	45.4
Monarch	614	465	149	24.3
French Varieties				
Moulhouse	880	510	370	42.1
Rouge Fonce	817	550	367	40.1
Saint Michel	649	410	239	36.8
des Vertus	858	570	288	33.6
Lescure	602	560	42	7.0
EGYPTIAN VARIETY				
Giza 6	716	570	146	20.4

amount of their volatile sulphur during the process of dehydration. It was noticed that when some varieties lost 7 per cent of their volatile sulphur others lost as much as 47.3 per cent.

All the varieties listed in Table (7) were grown in Harlington during the season 1952. From the table, it can be seen that all the varieties showed a loss in their volatile sulphur which was between 9.2 and 34.5 per cent.

From the results obtained in 1951 and 1952 it is evident that drying affected the volatile sulphur content of the onion, some varieties lost almost half their volatile sulphur content. It is also obvious that the loss in the volatile sulphur, of the different varieties, during the process of dehydration in the two seasons was not consistent.

Stephenson (5) reported that flavour formation in onions and garlic is an enzymic reaction. Cavalitio, Baily and Bucks (50) prepared an odourless and tasteless powdered garlic by destroying the enzyme before any cleavage of the precursor could occur. Stephenson (5) stated that the enzyme and precursor cells are separate in the onion bulb or garlic clove.

When the onion bulb is sliced there is a rupturing of cells only at the cut surface. The lachrymator and sulphur

TABLE (7) EFFECT OF DEHYDRATION ON THE VOLATILE SULPHUR CONTENT OF DIFFERENT VARIETIES OF ONIONS (1952)

Variety	Volatile Sulphur Content		Amount lost during drying	
	Fresh Samples	Dried Samples		
French Varieties:	p.p.m.	p.p.m.	p.p.m.	per cent.
St. Michael	1192	800	392	32.9
des Vertus	903	680	223	24.7
Rose Carole	791	670	121	15.3
Moulhouse (ronde)	724	630	94	12.9
Rouge Fonce	955	710	245	25.6
Rouge Niort	926	740	186	20.1
Lescure	978	640	338	34.5
Moulhouse (flat)	1096	810	286	26.1
Egyptian Variety				
Giza 6	750	600	150	20.0
English Varieties				
Prizetaker	822	540	282	34.3
Density	820	700	120	14.6
Best of All	793	610	183	14.7
Giant Zittau	760	690	70	9.2
A 1	900	690	210	23.3
Walker's Exhibition	717	630	87	10.8

bearing flavouring compounds are formed by cleavage of the precursor by the enzyme. Accordingly there is a loss in the volatile sulphur content at this stage in preparing the onion for dehydration. When entering the dehydrater the loss in volatile sulphur seems to continue. It is most likely that at this stage the greatest amount of volatile sulphur is lost. As quoted by Stephenson (5), unpublished work of Haagen-Smith and his co-workers showed that most of the oils isolated from onions have very low pressure under conditions of dehydration. In fact, in the earlier stages of dehydration the distinct aroma of onions was very noticeable, while in the later stages no aroma was detectable. Since the onion slices, in the earlier stages, still contain a high moisture content, it seems that the enzyme reaction continued until the samples reached the point where most of the moisture had evaporated. At such a point, the loss in volatile sulphur is likely to be at a minimum owing to the unfavourable conditions which stop the enzyme reaction. The results in table (5) shows that the greatest loss in volatile sulphur content occurred at the lower temperature and air velocities. At 50°C and 400 f.p.m. the percentage loss was 36.6 per cent. At such temperature and air velocity, longer time was needed for drying the onion owing to the slow rate of drying. Under these conditions it seems that the

enzyme reaction continued until most of the moisture had evaporated. On the other hand, raising the air velocity to 650 f.p.m. at the same temperature gave higher results than at 400 f.p.m., where the percentage loss was 32.5 per cent. At higher air velocities it can be seen that the loss in volatile sulphur was much less than at 650 and 400 f.p.m. Dehydrating the onion at 900, 1150 and 1400 f.p.m. and the same temperature, the percentage loss was 25, 27.5, and 26.3 per cent respectively. Raising the air velocity, at any given temperature, accelerated the drying rate and shortened the time needed for drying. Accordingly, the stage at which the enzyme became dormant was reached much earlier than when dehydrating at low air velocities and the same temperatures.

Raising the temperature from 50°C to 55°C all samples showed higher values for volatile sulphur. The highest values were recorded for samples dehydrated at 60°C and all air velocities. Dehydrating onions at temperatures higher than 60°C gave much lower values for the volatile sulphur. It seems that raising the temperature above 60°C. has a damaging effect on the enzyme. From the table, samples dehydrated at 65°C gave much lower results than those at 60°C., raising the temperature further, to 70° and 75°C., the onions lost much

more volatile sulphur than those dried at 65°C. Considering the effect of the higher temperatures, on the volatile sulphur content of the onion at different air velocities, it can be seen, from the table, that samples dehydrated at 400, 650 f.p.m. and at 65°, 70° and 75°C showed the lowest value for volatile sulphur. At higher air velocities, with the same temperature, the percentage loss was much less than samples dehydrated at lower air velocities. While the percentage loss, in volatile sulphur, for samples dehydrated at 65°C and 400 f.p.m. was 35 per cent, it was 20 per cent for those dehydrated at the same temperature and 1400 f.p.m. It is obvious, however, that onions dehydrated at 65° and 400 f.p.m. were subjected to the high temperatures longer than those dehydrated at the same temperatures and higher air velocities. Since prolonged dehydrated at high temperatures, and raising the temperatures higher than 60° increased the loss in volatile sulphur, it is likely that such temperatures destroyed the enzyme. The destruction of the enzyme by high temperatures is supported by the fact that onions cannot be successfully blanched. Blanching, once almost universally practised in the dehydration of vegetables, is intended to destroy the very enzyme upon which the flavour formation in onions depends. Stephenson (5) reported that blanched dehyrated onion is of little value as a flavouring material.

Furthermore onions cannot be sulphited for the same reason, since this chemical inhibits the vital enzyme activity. Sulphiting, can reduce the resulting flavour of the dried onion, to one third of the potency of an unsulphited control. Stephenson (5).

Supporting the enzyme theory of flavour formation in onion, Cavallito, Baily (51) isolated from garlic an oily substance which they named Allicin, which possesses the typical odour of garlic. Stolland Seebeck (53,54,55) synthesized Allicin, and were able to isolate, a sulphur containing, but odourless compound which they called Allin. On treatment with the specific enzyme Alliinase also found in garlic, Alliciini decomposes into Allicin.

From the general trend of all the experiments, which showed that the lowest percentage loss occurred at 60°C at all air velocities, it appears that this specific temperature had no damaging effect on the enzyme. Dehydrating the onion, at such a temperature and higher air velocities, seems to be the most favourable condition at which the dehydrated onion showed the highest values for volatile sulphur.

Since 60°C seems to have no damaging effect on the enzyme, it is obvious, that employing higher air velocities, can bring the onion to a stage at which the enzymic reaction ceases, more quickly than at lower air velocities.

THE EFFECT OF DEHYDRATION ON THE ASCORBIC ACID CONTENT OF THE ONION

THE EFFECT OF TEMPERATURES

The ascorbic acid content of onion samples dehydrated at various temperatures was determined and the results are shown in Table (8). Fig. (4) illustrates the effect of the varying temperatures on the ascorbic acid content.

From the results and the general trend of the curves it can be seen that heat has a destructive effect on the ascorbic acid. It is important to note that at all temperatures the onions lost a considerable amount of their ascorbic acid content. The difference in effect between the various temperatures is the amount of loss occurring during dehydration.

The results show that the lowest percentage of loss in the ascorbic acid content occurred in samples dehydrated at 60°C and at all air velocities. This loss ranged from 34.5 to 59.4 per cent.

Dehydration at lower temperatures than 60°C or higher all gave lower results, indicating higher losses. The lower temperatures used were 50° and 55°C., the higher ones 65°, 70°, and 75°C. Dehydrating at 50°C showed a percentage loss

TABLE (8) ASCORBIC ACID CONTENT OF ONION SAMPLES DRIED AT DIFFERENT TEMPERATURES AND AIR VELOCITIES

Air Velocity f.p.m.	Ascorbic acid content											
	50°		55°		60°		65°		70°		75°	
	mg/ 100g.	% loss	mg/ 100g.	% loss	mg/ 100g.	% loss	mg/ 100g.	% loss	mg/ 100g	% loss	mg/ loss	% loss
400	26.6	47.3	29.8	40.9	33.1	34.5	31.8	37.0	34.7	51.1	25.0	50.5
650	28.6	43.4	28.2	44.2	30.0	40.6	29.0	42.6	28.0	44.6	26.9	46.7
900	28.2	44.2	29.9	40.8	31.0	38.6	27.2	46.1	26.5	47.5	26.1	48.7
1150	24.9	50.7	26.8	46.9	28.9	42.8	26.0	48.7	24.1	52.3	24.4	51.7
1400	19.1	62.2	18.5	63.4	20.5	59.4	18.4	63.6	17.1	66.1	14.0	72.3

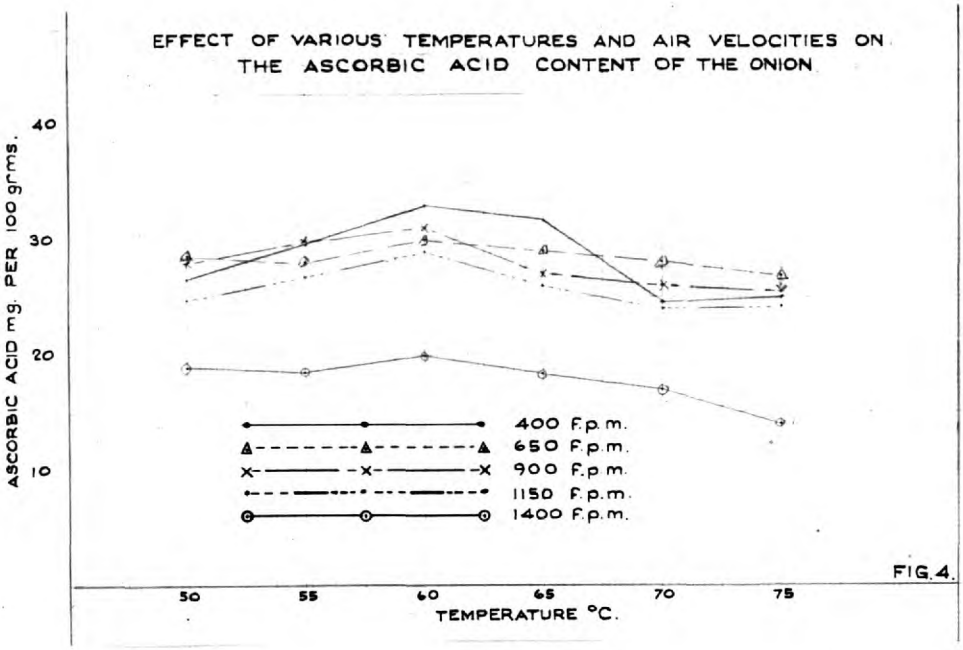

EFFECT OF VARIOUS TEMPERATURES AND AIR VELOCITIES ON THE ASCORBIC ACID CONTENT OF THE ONION
ASCORBIC ACID mg. PER 100 grms.
40
30
20
10
400 F.p.m.
650 F.p.m.
900 F.p.m.
1150 F.p.m.
1400 F.p.m.
50
55
60
65
70
75
TEMPERATURE °C.

FIG. 4.

from 43.4 to 62.2 per cent and at 55°C the losses ranged from 40.8 to 63.4 per cent according to the air velocity used. Onions dehydrated at 62°C showed greater losses of 37 to 63.6 per cent which is greater than those dehydrated at 60°C. At even higher temperatures 70 and 75°C., as can be seen, the loss of ascorbic acid was greater and ranged from 44.6 to 66.1 per cent for samples dehydrated at 70°C. and 46.7 to 72.3 per cent for those at 75°C.

Comparing the effect of the lower temperatures 50 and 55°C. with the higher ones 65°, 70° and 75°C. it is noticeable from the results in Table (8) that the latter temperatures had a greater destructive effect on the ascorbic acid than the former.

THE EFFECT OF AIR VELOCITIES*

The ascorbic acid content of onions dehydrated at various air velocities are in Table (8) and illustrated in Fig. (4).

Since all the dehydrated onions showed a considerable loss in the ascorbic acid at all air velocities, it is noticeable that the percentage loss differed according to the air velocity at which the onion was dehydrated. Samples

dehydrated at 50° and 400 f.p.m. lost 47.3 per cent while samples dehydrated at the same temperature and 1400 f.p.m. lost 62.2 per cent.

The general trend of the curves shows that the greatest loss in ascorbic acid encurred in samples dehydrated at the maximum air velocity 1400 f.p.m. and at all temperatures when the percentage losses were 62.2 at 50°c., 63.4% at 55°c., 59.4% at 60°c, 63.6% at 65°c, 66.1% at 70°c. and 72.3% at 75°c.

Dehydrating at 1150 f.p.m. gave much higher values for ascorbic acid than those dehydrated at 1,400 f.p.m. and lower than those dehydrated at 900, 650 and 400 f.p.m. The loss for onions dehydrated at 1150 f.p.m. was 50.7, 46.9, 42.8, 48.7, 52.3 per cent for the temperatures 50°, 55°, 60°, 65°, 70° and 75°C respectively.

It can be noticed from the curves that dehydration at lower air velocities had a less destructive effect on the ascorbic acid content than dehydration at 1150 and 1400 f.p.m.

Onions dehydrated at 400 f.p.m. and 50°C lost 47.8 per cent of their ascorbic acid while those dehydrated at the same temperature and 650 and 900 f.p.m. lost 43.6 and 44.2 per cent. On the other hand samples dried at 60°C. and 400 f.p.m. lost 34.3 per cent while those dehydrated

at 650 and 900 lost 40.6 and 38.6 per cent respectively. At 65°C the percentage loss was 37 per cent at 400 f.p.m., 42.6 at 650 f.p.m. and 46.1 at 900 f.p.m.

Surprisingly samples dehydrated at 70° and 75° and 400 f.p.m. showed much greater losses of 3.1 and 50.5 per cent than those dehydrated at the same temperatures and 650 and 300 f.p.m. where the percentage loss was 44.6 and 47.5., 46.7 and 48.7% respectively.

EFFECT OF DEHYDRATION ON ASCORBIC ACID CONTENT OF VARIOUS VARIETIES OF ONIONS

During the season 1951 nineteen varieties were dehydrated and their ascorbic acid estimated.

The results are presented in Table (9) compared with that of the fresh samples. It can be seen that a considerable amount of ascorbic acid was lost during dehydration. The losses between the varieties ranged from 22.5 to 69.6 per cent.

The same experiment was repeated during the season 1952 on different varieties all grown at Hallington and the results are shown in Table (10). It is obvious from the Table that all the varieties lost a great deal of their ascorbic acid during dehydration. The losses ranged from 20.81 to 67.1 per cent.

T A B L E (9) EFFECT OF DEHYDRATION ON ASCORBIC ACID CONTENT OF DIFFERENT VARIETIES OF ONIONS (1951)

Variety	Absorbic Acid Content		Amount Lost During Drying	
	Fresh Samples	Dried Samples		
English Varieties	mg/100g	mg/100g	mg/100g	per cent
Alisa Craig (1)	88.50	35.70	49.80	48.2
Southport Yellow Globe	72.39	22.00	50.39	69.6
Up to Date	35.57	23.00	12.57	35.4
Best of All	50.54	26.40	24.14	47.7
White Spanish	47.76	20.10	27.66	58.0
Giant Zittau (1)	59.64	26.70	32.94	55.0
Giant Zittau (2)	47.04	24.10	22.94	48.8
Bedfordshire Champion	80.32	27.40	52.92	65.7
Red Zittau	68.00	25.84	42.16	62.0
Dahniels Red Globe	88.61	45.72	42.89	48.4
Cambridge 10	67.71	52.50	15.21	22.5
Alisa Craig (2)	62.41	26.00	36.41	58.1
Monarch	68.16	35.00	33.16	48.8
French Varieties				
Maulhouse	51.08	32.50	18.58	36.2
Rouge Ponce	68.46	24.03	44.43	64.9
St. Michel	56.48	42.90	13.58	24.1
des Vertus	61.48	31.30	20.58	48.3
Liscure	97.24	46.30	50.94	52.4
Egyptian Variety				
Giza 6	89.03	28.60	60.43	67.9

T A B L E (10) EFFECT OF DEHYDRATION ON ASCORBIC ACID CONTENT OF DIFFERENT VARIETIES OF ONIONS (1952)

Variety	Absorbic Acid Content		Amount Lost During Drying	
	Fresh Samples	Dried Samples		
French Varieties	mg/100g	mg/100g	mg/100g	per cent
St. Michel	46.57	28.00	18.57	39.8
des Vertus	47.06	25.82	21.24	45.1
Rose Carole	35.50	25.96	9.54	26.9
Moulhouse (ronde)	45.86	32.72	13.14	28.6
Rouge Ponco	35.90	20.52	15.38	42.8
Rouge Nidrt	54.46	36.47	17.99	33.1
Lisoure	60.40	33.09	27.31	45.2
Moulhouse (flat)	38.88	29.27	9.61	24.8
Egyptian Variety				
Giza 6	38.45	27.53	10.92	28.4
English Varieties				
Prizetaker	64.35	43.63	20.72	32.1
Density	60.29	43.33	16.96	28.1
Best of All	56.08	38.10	17.98	32.0
Giant Zittau	54.45	43.09	11.36	20.9
A.I.	56.23	33.02	23.21	41.2
Walker's Exhibition	54.27	32.14	22.13	40.7

The results obtained in both years agree fairly well showing similar losses of ascorbic acid.

The thickness of the slices and the tray loads were constant, the only variables were the temperature and air velocities. It is these two factors which affected the ascorbic acid content of the onion during dehydration.

Ascorbic acid is sensitive to atmospheric oxidation. Since dehydration was carried out by the use of heat and air, it is obvious, that exposing the slices of the onion to the hot air, is the major factor in the loss of ascorbic acid during dehydration. The oxidation of ascorbic acid in vegetable tissues may be catalysed by ascorbic acid oxidase (Tauber and Kleiner (102); Kertesz, Dearborn, and Mack (103); Stone (104). It was reported by Cruess and Joslyn (8) that heating during dehydration is sufficient to inactivate ascorbic acid oxidase. Stone (104) was unable to find ascorbic acid oxidase in onion. In using the various temperatures and air velocities the oxidation of the ascorbic acid in the exposed slices occurred throughout the whole operation until the dried samples were packed. The loss in ascorbic acid started simultaneously with the peeling and slicing of the onion. When the sample reaches the dehydrater the oxidation grows faster owing to the hot draught of air entering the dehydrater. From the results

it can be seen that samples dehydrated at 50° and 55°C and all air velocities gave lower values than those dehydrated at 60° and the same air velocities. Since raising the temperature reduced the time required for dehydration, samples dehydrated at 50°C required a longer time than those dehydrated at 55°C while sample dehydrated at 60° required much shorter time than dehydrating at the previous temperatures. Consequently samples dehydrated at lower temperatures 50° and 55°C were exposed to the atmospheric oxygen much longer than those dehydrated at 60°C. Since ascorbic acid is very sensitive to atmospheric oxidation and dehydration at 50° and 55°C required much longer time than dehydration at 60°C., it is obvious that the loss in ascorbic acid owing to oxidation, was much greater for samples dehydrated at the lower temperatures than those at 60°C. These results are in agreement with those of Cruess and Mackinney (3) who stated that a shorter dryingtime, at 150° to 160°F. is less destructive to vitaim C. than a longer period at 120°F.

Raising the temperature to 65° the curve for the ascorbic acid declined. The time required for dehydration at 65°C was shorter than that required for dehydration at 60°C. Accordingly the destruction of the ascorbic acid by atmospheric oxidation was less at 65°C. than at 60°. This indicates that

besides the loss of ascorbic acid by oxidation at 65° there seems to be a further destruction of the ascorbic acid by the higher temperature. The effect of the high temperatures can be further noticed when raising the temperatures to 70° and 75°C. It can be seen from Table (4) that the percentage loss in ascorbic acid at higher temperatures were much greater than the lower ones 50° and 55°, although the time required for drying at high temperatures was much shorter than that at lower temperatures. The percentage loss in ascorbic acid for samples dehydrated at 50° and 55°C. ranged from 43.4 to 62.2 per cent and 40.8 to 63.4 per cent respectively, while the range for those dehydrated at 70° and 75°C was from 44.6 to 66.1 per cent and 46.7 to 72.3 per cent.

The loss in ascorbic acid content of the onion with the variation of the air velocities, appears to be greater at higher air velocities than the lower ones.

From the Table it can be seen that the most destructive conditions for ascorbic acid occurred with samples dehydrated at an air velocity of1,400 f.p.m. At such an air velocity the loss of ascorbic acid ranged from 62.2 to 72.3 per cent. Dehydration at 1,150 f.p.m. showed a less destructive effect on the ascorbic acid than dehydration

at 1400 f.p.m. where the percentage loss ranged from 42.8 to 52.3%. At much lower air velocities, 900, 650 and 400 f.p.m. onions showed higher values for the ascorbic acid than those dehydrated at higher air velocities. Dutcher (17) recommends rapid drying at relatively highe temperatures. He reported, "If plant tissues are dried rapidly at relatively high temperatures to ensure the inactivity of enzymes, it is found that vitamin A and C are preserved much more effeiently than when the drying process is conducted over longer periods at lower temperatures. If it is possible to eliminate atmospheric oxygen the amount of the original vitamin preserved will be greater". Chace (105) found that a better vitamin retention in hot rapid drying than a slower cooler operation.

The combined effect of the temperatures and air velocity on the ascorbic acid, can be seen from the table, the minimum loss occurred in samples dehydrated at 400 f.p.m. and 60°C. It is also noticeable, that the loss in ascorbic acid during dehydration differed according to the temperatures and air velocities used. The higher air velocities and temperature had the most destructive effect, while lower air velocities and 60°C seems to be the most favourable conditions in preserving ascorbic acid during dehydration.

THE EFFECT OF DEHYDRATION ON THE SUGAR CONTENT OF THE ONION

The sugar content of onions dehydrated at various temperatures and air velocities are shown in Table (11). When comparing the sugar content of the dehydrated onion with fresh onion having a sugar content of 31.7 per cent reducing sugars, 18.8 reducing and 50.5 per cent total sugars, it can be noticed that varying conditions of dehydration influenced the sugar content.

The conditions under which the inion was dehydrated can be divided into two groups. The first group# includes the high temperatures of 65°, 70 and 75°C. The second group includes the lower temperatures of 60°, 55°, and 50°C. From the table the first group of temperatures showed a noticeable effect on the reducing sugars at all air velocities. Comparing the effect of these temperatures on the reducing sugar content, it can be seen that the dehydration at 70° and 75°C and all air velocities, showed lower values than those dehydrated at 65°C. The lowest values of 26.3 and 26.6 per cent, for the reducing sugars occurred in samples dehydrated at 70° and 75°C. and 1,400 f.p.m. respectively. Reducing the air velocity to 1,150 and 900 f.p.m. the reducing sugars showed higher values of 28.5 and 28.2 per cent at the same

T A B L E (11) SUGAR CONTENT OF ONIONS DEHYDRATED AT VARIOUS TEMPERATURES AND AIR VELOCITIES

	Sugars per cent.					Temp. °C.
	400 fpm	650 fpm	900 fpm	1150 fpm	1400 fpm	
	per cent	per cent	per cent	per cent	per cent	
Reducing Sugars	29.5	29.4	28.7	28.2	26.6	75
Non-Reducing Sugars	18.5	19.3	19.0	19.2	18.5	
Total Sugars	48.0	48.7	47.7	47.7	45.1	
Reducing Sugars	29.5	29.3	28.8	28.5	26.3	70
Non-Reducing Sugars	18.5	18.9	19.0	18.9	18.7	
Total Sugars	48.0	48.2	47.8	47.4	45.0	
Reducing Sugars	30.5	30.2	30.8	30.3	30.1	65
Non-Reducing Sugars	18.8	18.8	18.9	17.9	18.9	
Total Sugars	49.3	49.0	49.7	48.2	49.0	
Reducing Sugars	31.8	31.2	31.5	30.6	31.0	60
Non-Reducing Sugars	19.6	18.8	18.6	18.5	18.7	
Total Sugars	51.4	50.1	50.1	49.1	49.8	
Reducing Sugars	30.5	31.2	30.3	31.2	30.5	55
Non-Reducing Sugars	19.2	18.8	18.8	18.8	19.5	
Total Sugars	49.7	50.0	49.1	50.0	50.0	
Reducing Sugars	31.8	31.0	31.2	31.1	31.0	50
Non-Reducing Sugars	18.2	18.9	19.2	19.2	18.8	
Total Sugars	50.0	49.9	50.4	50.3	49.8	

temperatures than those samples dehydrated at 1400 f.p.m. Lowering the air velocity still further to 650 and 400 f.p.m. higher values for the reducing sugars were obtained. At 70 and 75°C. and 650 f.p.m. the reducing sugars content of onions were 29.3 and 29.4 respectively while at 400 f.p.m., and the same temperatures, the values were 29.5 per cent. It can be seen from the Table that dehydration at 65° had a lesser effect on the reducing sugar content than that of 70° and 75°C. The values for the reducing sugars content of onions dehydrated at 65° were 30.1 to 30.8 at all air velocities.

In considering the second group of temperatures which includes the lower ones, it is noticeable from the table that there was no considerable difference between the reducing sugars of the dehydrated and the fresh onions.

The non-reducing sugars seems to be not affected by the process of dehydration, since the results show that no appreciable difference occurred to the non-reducing sugars at the various temperatures and air velocities. The effect of the various temperatures and air velocities on the total sugars can only be seen whenever the reducing sugars are affected. It is obvious, however, that higher temperatures had an effect on the total sugars of the onion.

During the season 1951, different varieties of onions, including English, French and Egyptian varieties were dehydrated and their sugar content estimated. The results of the dehydrated varieties in comparison with those of the fresh are shown in Table (12). Comparing the sugar content of the dehydrated samples with those of the fresh it was found that there was no significant difference between the two. Furthermore there was no significant difference between the reducing and the non-reducing sugars of the dehydrated and the fresh.

The experiment was repeated during the season 1952 on English, French and Egyptian varieties grown at Harlington. The results are shown in Table (13) for the fresh and dehydrated samples. The total sugars, the non-reducing sugars and the reducing sugars, showed no significant difference from those of the fresh samples which confirms the results obtained during the Season 1951. The Onion is one of the vegetables which are not blanched before dehydration, accordingly, no losses in the sugar content could occury in preparing the onions for dehydration. The losses in the sugar content can only be due to the varying temperatures and air velocities used for dehydration. Using high temperatures for dehydration had a damaging effect and

TABLE (12) EFFECT OF DEHYDRATION ON THE SUGAR CONTENT OF DIFFERENT VARIETIES OF ONIONS

(1951)

Variety	FRESH			DRIED		
	Total Sugars	Reducing Sugars	Non Reducing Sugars	Total Sugars	Reducing Sugars	Non Reducing Sugars
	per cent	per cent	per cent	per cent	per cent	per cent
Alisa Craig 1	85.3	31.3	54.1	85.0	30.2	54.8
Southport Yellow Globe	74.4	30.4	44.1	73.4	29.3	44.1
Up to Date	51.3	13.7	37.6	51.2	14.3	37.0
Best of All	41.0	25.3	15.7	41.2	25.9	15.3
White Spanish	59.3	24.2	35.1	61.0	23.6	37.4
Giant Zittau 1	64.1	21.6	42.5	63.6	22.6	41.1
Giant Zittau 2	62.1	24.5	37.6	60.3	24.6	35.7
Bedfordshire Champion	60.1	20.0	40.2	57.9	19.0	39.0
Red Zittau	51.0	24.2	26.9	54.4	24.0	30.5
Dahneils Red Globe	56.4	21.1	35.3	53.2	16.0	37.7
Cambridge 10	56.6	25.1	31.6	57.9	22.4	35.5
Alisa Craig 2	54.42	33.8	20.7	58.0	33.6	24.4
Monarch	53.2	21.0	32.2	49.5	23.1	26.5
FRENCH VARIETIES						
Moulhouse	51.3	20.9	30.5	51.0	20.5	30.5
Rouge Fonce	56.8	24.7	32.1	53.9	24.1	29.8
Saint Michel	66.8	30.2	36.6	66.9	27.6	39.3
Jaune Paille des Vertus	58.9	30.7	28.1	57.3	28.2	29.1
Lescure	48.0	40.0	8.0	48.9	39.9	9.0
EGYPTIAN VARIETY						
Giza 6	68.0	17.2	50.9	66.3	17.6	48.7

TABLE (13) EFFECT OF DEHYDRATION ON THE SUGAR CONTENT OF DIFFERENT VARIETIES OF ONIONS (1952)

Variety	FRESH			DRIED		
	Total Sugars	Reducing Sugars	Non Reducing Sugars	Total Sugars	Reducing Sugars	Non Reducing Sugars
	per cent	per cent	per cent	per cent	per cent	per cent
St. Michel	61.8	20.1	41.7	58.8	20.6	38.0
Les Vertus	62.1	23.8	38.3	60.4	25.5	34.9
Rose Carole	59.8	10.9	48.9	59.5	6.3	53.2
Moulhouse (ronde)	61.8	17.4	44.4	60.6	15.1	45.5
Rouge Fence	64.4	11.5	52.9	64.7	13.9	50.8
Rouge Niort	56.7	25.2	31.5	63.0	30.1	32.9
Lescure	60.8	52.1	8.7	61.1	49.2	11.9
Moulhouse (flat)	64.7	19.9	44.8	63.0	18.9	44.1
Giza 6	61.6	21.3	40.3	61.0	20.1	40.9
Prizetaker	58.5	13.6	45.9	59.8	17.1	42.7
Density	56.2	22.1	34.1	58.2	25.3	32.9
Best of All	61.8	14.2	47.6	62.9	13.4	49.5
Giant Zittau	54.9	22.9	32.0	56.9	21.4	35.5
A.I	59.4	24.7	34.7	60.1	22.4	37.7
Wilkins Exhibition	57.1	24.8	32.3	57.9	24.9	33.0

charring occurred with all samples dehydrated at such temperatures and air velocities. Dehydrating at 75°C had a more damaging effect on onions than that of 70°C. From the results it can be seen that the reducing sugars were affected only when the onions were dehydrated at such high temperatures. It is interesting to note that the degree of charring seems to be in accordance with the effect on the reducing sugars. The Table shows that onions dehydrated at 70° and 75°C. and 1400 f.p.m. had the lowest values for the reducing sugars of 26.3 and 26.5 respectively. At these particular temperatures and air velocity charring was much more pronounced than at the same temperatures and lower air velocities. Dehydration at the same temperature and lower air velocities showed higher results for the reducing sugars than those dehydrated at 1400 f.p.m. This can be seen from the Table where the results for the reducing sugars were 28.5 and 28.2 per cent for samples dehydrated at 1150 f.p.m., 28.8 and 28.7 per cent for those dehydrated at 900 f.p.m., 29.3 and 29.4 for 650 f.p.m. and 29.5 per cent for 400 f.p.m.

The effect of the temperatures can be clearly realised when dehydrating at 65°C. At such a temperature the reducing sugars were not affected as much as when

dehydrating at 70° and 75°C. Onions dehydrated at 65° showed higher values for the reducing sugars of 30.1 to 30.8 per cent, than those at 70 and 75°C. The effect of such a temperature on the onion was not so damaging as that of the higher temperatures Although charring occurred, the dehydrated onions had a much lighter colour than those dehydrated at 70° and 75°C.

When dehydration was carried out at even lower temperatures of 60°, 55° and 50°C., it can be seen from the Table that no appreciable difference between the dried and the fresh occurred in the reducing sugars.

The dehydration of various varieties of onions in the seasons 1951 and 1952 at 60°C. and 1400 f.p.m. showed that no sighificant difference occurred to the sugar content of the onion. This supports the above results, that sugars were not affected by dehydration, at temperatures not exceeding 60°C. It is important to note that no charring occurred to the onions dehydrated at 60°, 55 and 50°C.

C H A P T E R IV

FIELD EXPERIMENTS

During 1951 a large number of varieties of mature onions were purchased for the purpose of studying their constituents, keeping quality and the effect of dehydration. Thirteen English varieties were bought from different firms, five French varieties and eleven seed samples of different varieties were imported from France, and an Egyptian variety and a sample of its seeds were imported from the Egyptian Ministry of Agriculture in Cairo.

It has been intended to study the constituents of the onion during growth but the crop grown at Harlington Field Station for that purpose failed owing to a prolonged drought. So this part of the work had to be postponed to the following season.

During the Season 1952, six English, eight French and the Egyptian varieties were sown in Harlington on the 26th March 1952. Although all the varieties were grown in the same soil, the English varieties were poor while the French and the Egyptian varieties were very successful. So the study of the constituents of the onion during different stages of maturity was carried out on the French and the Egyptian varieties only.

Samples were taken every three weeks starting from 30th June when the plants started forming bulbs.

A representative sample of not less than 150 plants was taken from each variety on the first and second dates of sampling. Towards the maturity of the crop samples contained from 80 to 60 plants. All samples were taken to the laboratory where analysis was carried out immediately.

When the drop was harvested the bulbs were spread in a shed on wooden shelves and samples were taken within two weeks.

For the storage experiment, the bulbs were stored on wooden shelves under ordinary conditions and samples were taken monthly starting on the 15th October, 1952.

It is important to note that although the Egyptian variety grew well at Harlington, the bulbs were much smaller compared with the bulbs of the same variety imported in 1951 from Egypt. So, there were not enough Egyptian onions for the storage experiments; this was also the case with the English varieties.

PREPARATION OF THE BULBS BEFORE ANALYSIS

1. The Immature Onions.

The green tops were removed at the juncture of the green and white portions of the stem. The roots were

removed and adhering soil particles were rubbed off with a dry cloth.

2. The mature onions.

The outer dry leaves were removed, care being taken not to remove any of the inner tissues. The residue of the dry roots was cut off.

C H A P T E R V

STUDIES ON VOLATILE SULPHUR COMPONENTS IN ONIONS

Method of Analysis.

The method developed by "Currier" (49) was used in determining the volatile sulphur content in onions. This method, involving the so-called Caro's reaction, is based on the reaction between p-aminodimethylaniline hydrochloride and H_2S in the presence of ferric ammonium sulphate to give methylene blue.

Reagents used:

1. p. Aminodimethylaniline monohydrochloride: 0.5 gram was dissolved in 200 ml of water containing 5 ml. of concentrated H_2SO_4. 45 ml. of additional H_2SO_4 was added with cooling and the solution diluted to 1 litre.

2. Basic aluminium acetate: 5 per cent suspension in water

3. Ferric ammonium sulphate: 12.5 per cent in 2.5 per cent by volume H_2SO_4 (113 grams $Fe_2(SO_4)_3(NH_4)_2SO_4\ 24H_2O$ per 500 ml of solution)

4. Sulphuric acid solution: 50 ml. of concentrated acid diluted to one litre.

5. Sodium sulphide standard: 0.1875 gram $Na_2S\ 9H_2O$ made to one litre with water recently boiled. Each ml. will contain 0.025 mg. of sulphur. The sulphur was standardized iodometrically.

Determination of volatile sulphur content in fresh onions.

200 grams. of a representative sample (radial sections from at least 20 bulbs) with 100 grams of recently boiled water were placed into a blender. The sample was blended until a homogeneous pulpy mass was obtained. 12 to 15 grams of the pulp were weighed and washed immediately into a one litre volumetric flask half full of water, eight ml. of aluminium acetate suspension were added and the solution diluted to volume The solution was allowed to stand for 30 minutes. 50 to 100 ml. were filtered through a No.1 filter paper into a small conical flask.

To 10 ml. of the filterate in a small 30 ml. bottle fitted with a plastic cap, four ml. of the sulphuric acid solution were added. Air was swept out above the liquid with a stream of nitrogen. The bottle was then closed tightly and placed in an autoclave and five pounds pressure was maintained (109°C) for one hour. After cooling 7.5 ml. dimethylaniline solution, and 50 mg of pure zinc powder were added. The cap was replaced immediately and the bottle agitated slightly to

assure even distribution of zinc. After 30 minutes the cap was removed carefully and 2 ml. of ferric ammonium sulphate solution was added. The cap was replaced immediately and the bottle inverted a dozen times. After two minutes, the solution was filtered through a small plug of fine glass wool inserted in the stem of a small funnel into 50 ml. volumetric flask. The solution then diluted to volume with distilled water. The intensity of the blue colour was measured by Hilger Bioch. Absorpiometer and the amount of sulphur present was computed by referring to a standard sodium sulphide curve, fig. (5).

A reagent blank prepared in the same manner was subtracted from the reading of the sample.

Dried Onions:

The dried onions were ground to at least 20 mesh powder (5 mm. sieve). 0.5 gram of the powder was weighed accurately into a 250 ml. volumetric flask half full of water. 2 ml. of aluminium acetate suspension was added and the solution diluted to volume. Then the determination carried out as for fresh onions.

Standard:

A series of dilutions of the fresh sodium sulphide solution was prepared. To 10 ml. aliquot four ml. of sulphuric acid solution and 7.5 ml. of dimethylaniline reagent were added followed by 2 ml. of ferric alum solution and then treated as above.

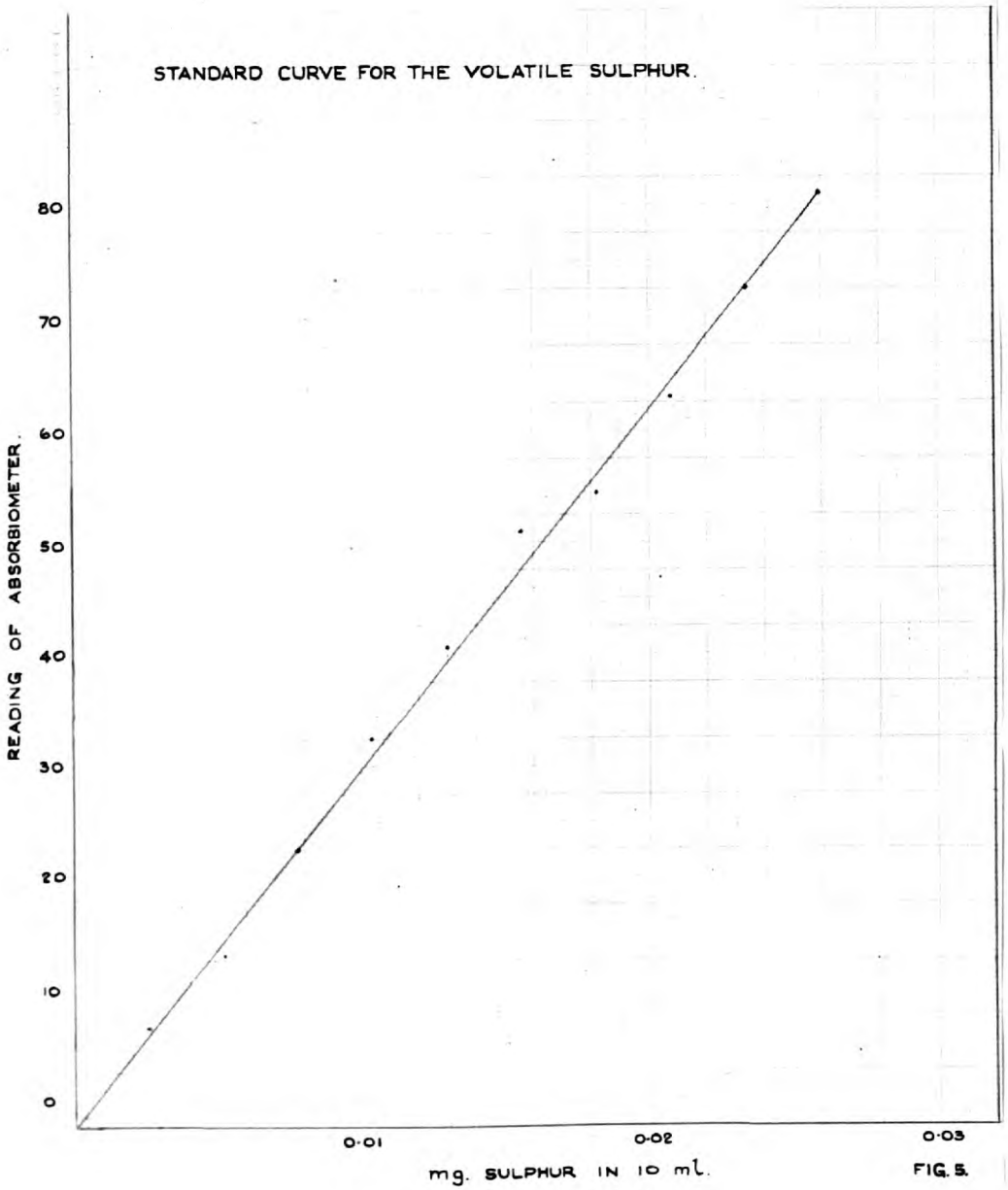

STANDARD CURVE FOR THE VOLATILE SULPHUR.
READING OF ABSORBIOMETER.
0
10
20
30
40
50
60
70
80
0·01
0·02
0·03
mg. SULPHUR IN 10 ml.

FIG. 5.

A standard curve was drawn and is shown in fig. (5)

In preparing the samples care was taken to minimize the volume of air present during blending. A 30 minute extraction period was found sufficient to produce a concentration equilibrium throughout the solution and the use of a 5 mm. sieve for onion powder, where blending is omitted, indicated equally rapid extraction (Currier) (49).

By using air free water in making up filtrates, the intercellular air still in the pulp or powder is dissolved, permitting the fragments to sink to the bottom of the flask.

Basic aluminium acetate was recommended by Currier (49) and successfully used by Potter and Jones (106) in separating protein sulphur and sulphide sulphur.

It was assumed by Platenius (30) that the essential oil of onion exists in glocosidal combination, since upon distillation a very low yield of volatile sulphur resulted. The necessity of hydrolysis was confirmed by Currier (49).

To prevent leakage from the bottle during heating, circular pieces of soft plastic previously boiled in alkali to remove any traces of sulphur, were inserted within the bottle cap. The caps were dipped in hot water before closing the bottles to produce a better seal.

The development of colour is almost immediate. A pink tint appearing at first rapidly disappears.

Escape of volatile sulphur during blending is minimized by means of the adjustable cover. The replacement of air in the bottle above the solution with nitrogen and use of air free water in preparing the filterate were a measure to minimize the oxidative loss in hydrolyzing the filterate at the high temperature employed (100°C)

RESULTS AND DISCUSSION

Volatile sulphur content of different varieties of onions.

During the season 1951 different varieties of onions were examined for their volatile sulphur content. The varieties were English, French and Egyptian.

The results are summarized in table (14). The different varieties of onions are listed in ascending order of their volatile sulphur content and grouped separately according to their origin.

Table (14) indicates that different varieties of onions differ from each other in their volatile sulphur content. Some varieties contain nearly twice as much volatile sulphur as others.

In 1952 different varieties of onions were grown at Harlington and their volatile sulphur content estimated. The results are shown in table (15).

T A B L E (14) VOLATILE SULPHUR CONTENT AND PERCENTAGE OF DRY MATTER OF DIFFERENT VARIETIES OF MATURE ONIONS - (1951)

(Fresh Basis)

Variety	Volatile Sulphur Content	Dry Matter Content
ENGLISH VARIETIES:	p.p.m.	per cent.
Alisa Craig 1	65.9	10.8
Dahneils Red Globe	66.5	10.8
Best of All	72.1	12.9
Monarch	80.5	13.1
Southport Yellow Globe	82.1	11.7
Red Zittau	87.5	12.7
Alisa Craig 2	91.7	9.1
Bedfordshire Champion	96.5	12.2
Cambridge 10	98.0	11.8
White Spanish	102.7	13.4
Giant Zittau 1	105.6	14.2
Up to Date	112.2	15.6
Giant Zittau 2	122.9	14.2
FRENCH VARIETIES:		
Lescure	50.0	8.3
Saint Michel	72.1	11.1
Moulhouse	97.7	11.1
Jaune Paille de Vertus	92.7	10.8
Rouge fonce	125.7	13.7
EGYPTIAN VARIETY:		
Giza 6	126.1	17.6

T A B L E (15) VOLATILE SULPHUR CONTENT AND PERCENTAGE OF DRY MATTER OF DIFFERENT VARIETIES OF MATURE ONIONS - (1952)

(Fresh Basis)

Variety	Volatile Sulphur Content	Dry Matter Content
FRENCH VARIETIES:	p.p.m.	per cent
Lescure	97.8	10.0
Moulhouse (ronde)	105.0	13.5
des Vertus	129.1	14.3
Rouge Niort	130.2	14.1
Rose Garde	139.3	17.6
Rouge Fonce	142.3	14.9
Moulhouse (flat)	147.9	13.5
Saint Michel	170.5	14.3
ENGLISH VARIETIES:		
Walker's Exhibition	88.97	12.4
Monarch Silver King	104.2	13.5
A.I.	105.4	11.7
Density	112.4	13.7
Best of All	113.4	14.3
Prizetaker	126.7	15.4
EGYPTIAN VARIETY:		
Giza 6	106.6	14.2

Referring to table (15) although the varieties of onions were grown in the same soil and under the same conditions it is seen that they differ considerably in their volatile sulphur content, the difference in some varieties being twice as much as other varieties which confirms the results of the previous season.

From the study of the dry matter content of the different varieties during the two seasons 1951 and 1952, it can be seen from the tables (14) and (15) that the varieties which are low in volatile sulphur content are relatively high in their moisture content, while those which are high in their volatile sulphur are relatively low in their moisture content.

Tissue of high water content is likely to be low in volatile sulphur, at least when calculated on a fresh basis, for a sample of such tissue contains less dry matter than the same weight of tissue lower in water and is likely to contain less volatile sulphur, one constituent of the dry matter.

This inverse relationship was also reported by Eaton (35) when studying the volatile sulphur content of black mustard plant. He found that the tissue with the highest water content has also the lowest fresh weight of volatile sulphur.

Although this was the general trend, yet there were

several exceptions. Alisa Craig 1 with the lowest and Jaune Paille des Vertus with one of the highest sulphur contents included in the study carried out in the season 1951 both had a water content of 89.2 per cent. These exceptions can also be seen from table (15) when the varieties were grown under the same conditions in the season 1952. The variety Moulhouse (bulb flat) one of the highest varieties in volatile sulphur (147.9 p.p.m.) and the varieties Moulhouse (bulb ronde and Monarch Silver King with a low volatile sulphur (105.0 and 104.2 p.p.m. respectively) all had the same water content of 86.5 per cent.

Platenius and Knott (33) grew a number of varieties of onions and also found that in general the pungency varied inversely with the water content, but the relationship was not exact. For example the most pungent variety and two decidedly less pungent ones had about the same water content.

Jones and Bisson (14) concluded that mild varieties with rather poor storage qualities have the highest water content while the most pungent and best keeping varieties have the lowest water content. This and Platenius's (30) theory that pungency is proportional to the volatile sulphur content were to some extent confirmed from the behaviour of the varieties Lescure and Saint Michel. The first variety

had the highest moisture content and the lowest volatile sulphur content,
did not keep at all during storage even for one month. On the other hand the third variety Saint Michel with the highest volatile sulphur content and relatively high dry matter kept very good during storage.

It can be seen from table (15) that some varieties with a relatively high water content contained also a high volatile sulphur content. This can be seen from the variety Rose Garole and the variety Saint Michel. The former had a volatile sulphur content of 139.3 p.p.m. and 82.7 per cent water content while the latter of 170.5 p.p.m. and 86.7 per cent volatile sulphur and water content respectively. This indicates that the decrease in the volatile sulphur of the tissue higher in water content is not due entirely to a dilution of volatile sulphur with water, but there is actually less volatile sulphur in proportion to the remainder of the dry matter.

Accordingly genetic factors seem likely to have great influence on the volatile sulphur content.

COMPARISON OF SOME VARIETIES GROWN IN DIFFERENT LOCALITIES:

In the season 1951 two samples of the variety Giant Zittau and Alisa Craig were obtained from different parts in England. Table (14) indicates that the two different samples from the same variety differ considerably in their volatile

sulphur content. One sample of Alisa Craig 1 had much larger bulbs than the other sample, Of Alisa Craig 2, the same thing occurred with the variety Giant Zittan. Since each sample was grown under different conditions it is likely that the different environmental and soil conditions were the cause of this large variation in volatile sulphur content between the two samples of the same variety. The increased production of the tissue might have been additional factor in decreasing the volatile sulphur content.

Platenius and Knott (33) found that irrigated onions contained more water and less volatile sulphur than non irrigated ones. The former bulbs were larger than the latter. They also found that climatic conditions and the amount of sulphur in the soil affect the volatile sulphur content of the onion. They found a definite though not proportional relationship between pungency and the sulphur content of the soil.

The French and the Egyptian variety imported from France and Egypt in 1951 were quite different, in the volatile sulphur content, from the same varieties grown from imported seeds at Harlington in 1952. The results of the two seasons are summarized in table (16).

The French varieties, when grown at Harlington showed a remarkable increase in volatile sulphur content. The increase

T A B L E (16) CHANGES IN THE VOLATILE SULPHUR CONTENT OF DIFFERENT VARIETIES OF ONIONS ACCORDING TO THEIR LOCATION (FRESH BASIS)

Variety	1951		1952	
	Imported		Grown in England	
	Volatile Sulphur Content	Dry matter content	Volatile Sulphur Content	Dry matter content
	p.p.m.	per cent	p.p.m.	per cent
Lescure	50.0	8.3	97.8	10.0
Saint Michel	72.1	11.1	170.5	14.3
Moulhouse (bulb flat)	97.7	11.1	147.9	13.5
des Vertus	92.7	10.8	129.1	14.3
Rouge Fonce	125.7	13.7	142.9	13.5
Giza 6	126.1	17.6	106.6	14.2

in some varieties, doubled. Although the volatile sulphur content of the variety Jaune de Lescure increased when grown at Harlington in 1952, it still showed the lowest value. It is also noticeable that while its dry matter content increased it remained the lowest. Surprisingly the variety Saint Michel was found to have the highest volatile sulphur content, although when imported from France the variety was one of the lowest.

On the other hand, the Egyptian variety Giza 6 showed a decrease in volatile sulphur content. It should be noticed that this variety was not very successful at Harlington its bulbs being small.

It is evident that the environmental conditions and the type of soil is quite different between France, Egypt and England. These different conditions under which the various varieties were grown are likely to be an influencing factor in determining the volatile sulphur content of the onion.

Platenius and Knott (33) reported that the most pungent onions were harvested from peat soil while the mildest from sandy soil.

Accordingly, different growing conditions, soil type and ecology might be more important than genetic factors in determining the volatile sulphur content of the onion.

THE EFFECT OF GROWTH ON THE VOLATILE SULPHUR CONTENT OF THE ONION

In order to study whether definite fluctuations occur in the volatile sulphur content during the growth of the onion plant, ten French varieties and one Egyptian variety were grown at Harlington during the season of 1952. Starting June 20th samples were taken for analysis every 3 weeks. The results are summarized in table (17). Fig. (6) illustrates the changes in the volatile sulphur content which occurred during the growth of the onion plant. The curves indicate a rapid increase in the volatile sulphur until the plant approached maturity. The peaks of the curves for the variety Moulhouse (bulbs ronde) was reached before the harvest when the tops began to fall over. When allowed to remain for some time in the field the volatile sulphur content decreased slightly. The rest of the varieties showed a steady increase till the plant reached maturity.

From the general trend of the curves the changes in the volatile sulphur during the growth of the plant can be divided into three stages. The first stage which is between the first and the second sampling, the increase in the volatile sulphur was relatively slow. The second stage is characteristic of a very rapid increase in the volatile sulphur which occurred between the second and fourth sampling. The third stage which

T A B L E (17) VOLATILE SULPHUR CONTENT OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH. (DRY BASIS)

Variety	Volatile Sulphur Content p.p.m. Age in Weeks				
	12	14	17	20	23
St. Michel	506	642	661	866	1192
des Vertus	473	501	668	880	903
Rose Garole	447	488	539	735	791
Moulhouse (ronde)	371	404	684	845	724
Rouge Fonce	443	649	743	897	955
Rouge Niort	563	606	813	911	926
Lescure	460	465	535	961	978
Moulhouse (flat)	412	548	653	1080	1095
Giza 6	345	463	518	618	750

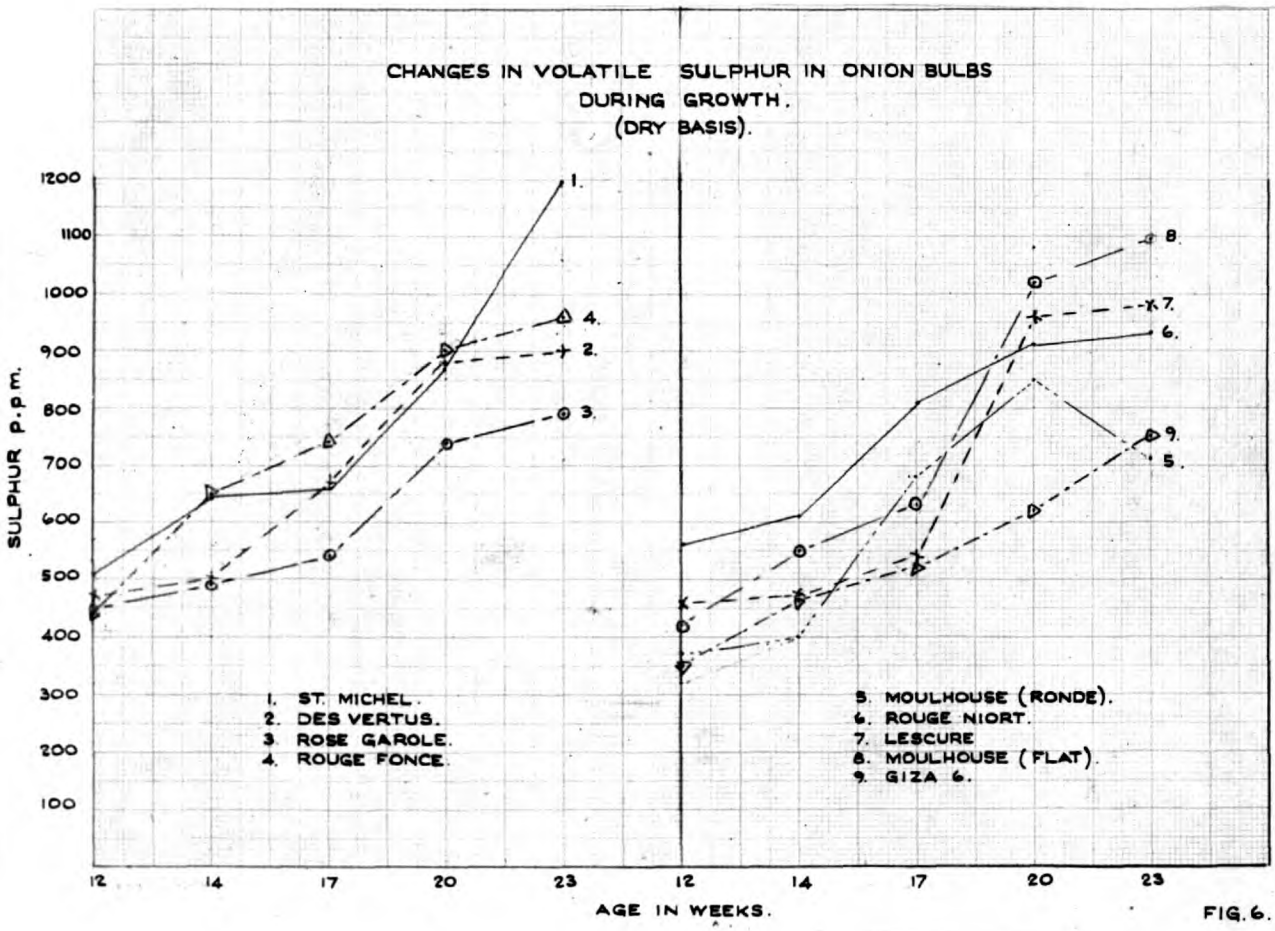

CHANGES IN VOLATILE SULPHUR IN ONION BULBS
DURING GROWTH.
(DRY BASIS).
SULPHUR p.p.m.
1200
1100
1000
900
800
700
600
500
400
300
200
100
12
14
17
20
23
AGE IN WEEKS.
1. ST. MICHEL.
2. DES VERTUS.
3. ROSE GAROLE.
4. ROUGE FONCE.
5. MOULHOUSE (RONDE).
6. ROUGE NIORT.
7. LESCURE
8. MOULHOUSE (FLAT).
9. GIZA 6.

FIG. 6.

is between the fourth and final sampling shows only a slight change, in fact one of the varieties showed a slight decline, in the volatile sulphur content. It is important to note that during the first stage when the plant was about ~~three~~ twelve weeks old the tops and the bulbs were small. During the second part the plants were much larger and the tops possessed a very high synthesizing power. During the final stage the tops began to fall over.

Since the onion bulb increased steadily in volatile sulphur as the plant advanced in growth, it seems that the volatile sulphur compounds were made mainly in the leaves, and a constant translocation from the leaves occurred during the growth of the plant. At the early stages when the increase in the volatile sulphur was relatively slow the plants had a very small top. As the plants grew older a rapid increase in the volatile sulphur occurred and during that stage the plants had a top of a very great synthesizing power. As the plants approached maturity the softening of the neck of the top occurred, due to the fact that new leaves were not being formed. It can be seen from the curves that at this stage the changes in the volatile sulphur were relatively smaller. Platenius and Knott (34) found that the percentage of volatile sulphur of onion bulbs increased steadily up to near the time

which the tops began to fall over. Eaton (35) reported that younger leaves in black mustard plants is much more pungent than older leaves and the younger the plant the more volatile sulphur found in its leaves.

The changes in the volatile sulphur, one constituent of the dry matter, cannot be entirely due to the changes in the dry matter of the bulb. The changes in the dry matter were a steady increase until the third sampling and then a decrease until the plant reached maturity. On the other hand the volatile sulphur continued to increase even after the dry matter decreased which indicates that the formation of the volatile sulphur compounds, which continued even after the dry matter decreased, was a result of the growth of the plant.

THE EFFECT OF STORAGE ON THE VOLATILE SULPHUR CONTENT OF THE ONION

To study the effect of storage on the volatile sulphur content of various varieties of mature onions, samples were taken monthly and their volatile sulphur estimated. The results are summarized in table(18). Fig. (7) shows that the volatile sulphur of all varieties increased as the storage progressed until the second month then decreased during the third month. It is noticeable that ~~the increase in the~~

T A B L E (18) EFFECT OF STORAGE ON THE VOLATILE SULPHUR CONTENT OF DIFFERENT VARIETIES OF ONIONS (DRY BASIS)

Variety	Volatile Sulphur Content p.p.m.			
	After harvest	1st month	2nd month	3th month
St. Michel	1192	1291	1098	1022
des Vertus	903	1033	1111	884
Rose Carole	791	793	981	1019
Moulhouse (ronde)	724	904	1225	1041
Rouge Fonce	955	1005	1181	960
Rouge Niort	926	982	1103	1066
Moulhouse (flat)	1095	1271	1355	1272

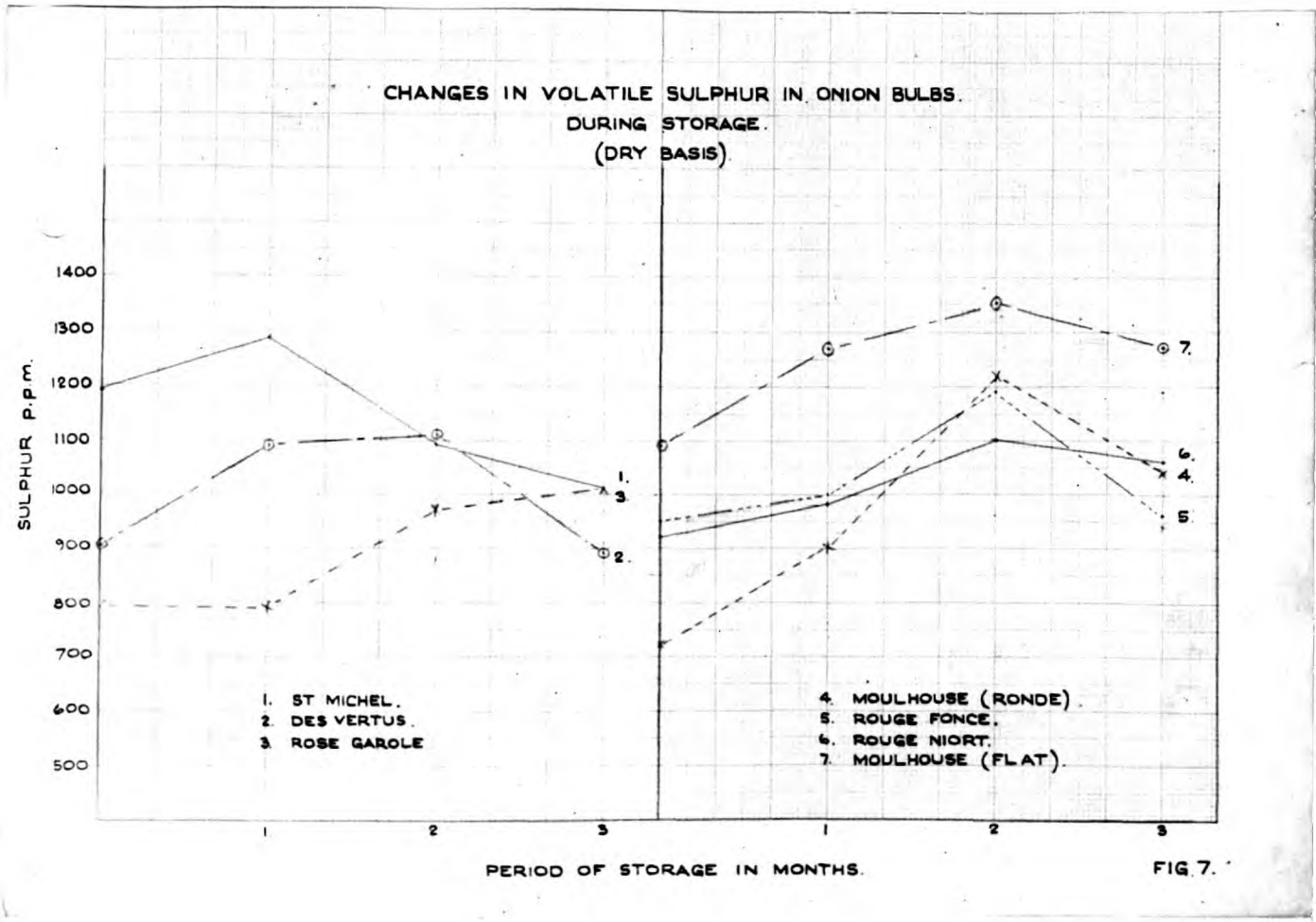

CHANGES IN VOLATILE SULPHUR IN ONION BULBS.
DURING STORAGE.
(DRY BASIS).
SULPHUR p.p.m.
1400
1300
1200
1100
1000
900
800
700
600
500
1
2
3
1
2
3
1.
3.
2.
7.
6.
4.
5.
1. ST MICHEL.
2. DES VERTUS.
3. ROSE GAROLE
4. MOULHOUSE (RONDE).
5. ROUGE FONCE.
6. ROUGE NIORT.
7. MOULHOUSE (FLAT).
PERIOD OF STORAGE IN MONTHS.

FIG. 7.

volatile sulphur of some varieties increased gradually followed by a slight decrease towards the end of the storage period. This was the behaviour of the varieties, Rouge Niort and Moulhouse (bulbs flat). The varieties Moulhouse (bulbs ronde) and Rouge Fonce showed a slow increase in volatile sulphur during the first month followed by a very rapid increase during the second month then a similar decrease during the third month of storage. The variety Rose Garole showed a slight increase in the volatile sulphur throughout the storage period. The variety St. Michel increased slightly during the first month then decreased rapidly towards the end of the storage period.

Platenius (33) found that the volatile sulphur of various varieties of onions during storage at 35°F. increased and that the increase was very slight at the end of the storage period. In fact he found that one variety showed a slight decrease in the volatile sulphur.

CHAPTER VI

STUDIES ON THE ASCORBIC ACID CONTENT OF THE ONION

METHOD OF ANALYSIS

Sampling.

During the first and second sampling, where the onion bulbs were small, a sample of about 70 bulbs was used, while the plants approached maturity the samples were composed of 30 to 40 bulbs.

The importance of proper handling of the samples for ascorbic acid determinations cannot be over-emphasized. The sampling and extraction of the onion bulbs were carried out with minimum delay so that no significant change in ascorbic acid could take place prior to analysis.

Since ascorbic acid is unevenly distributed within the bulb (Murphy) (62) care was taken to produce a representative sample. After the onion bulbs were cut and chopped, they were handled very quickly and blended with stablizing acid as quickly as possible to prevent undue oxidation of ascorbic acid. As much of the comminution as possible was conducted in the presence of the stablizing acid. The most suitable agent was found to be Metaphosphoric Acid. (Vavich, Stern and Guerrant) (107).

Dehydrated Samples.

The procedure for handling dehydrated onions was slightly different from that used for fresh samples. From 5 to 7 grams of dehydrated onions were first dehydrated with 100 ml of 3 per cent Metaphosphonic Acid for approximately 15 minutes after which it was blended and treated in the usual manner for analysis.

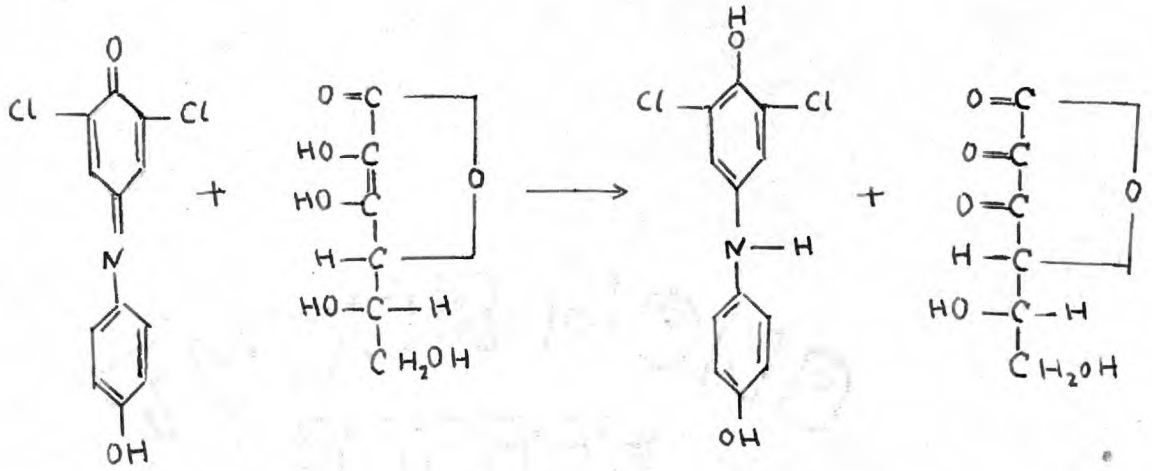
Since some varieties included in these experiments were coloured, two methods for determining the ascorbic acid content were used.

1. The 2,6 - Dichlorophenolindophenol visual titration method was used for the determination of the ascorbic acid content of the white varieties.

2. The Indophenol-xylene extraction method was used for the determination of the ascorbic acid content of the coloured varieties.

The Visual Titration Method.

This method is based upon the reduction of the dye, 2, 6 - dichlorophenolindophenol byan acid solution of ascorbic acid. In the absence of interfering substances, the capacity of an extract of the sample to reduce a standard solution of the dye, as determined by titration, is directly proportional to the ascorbic acid content.



Dye (Pink) Ascorbic Acid Dye (Colourless) Dehydrascorbic acid

Reagents:

1. 6 per cent metaphosphoric acid solution.
2. 3 per cent metaphosphoric acid solution.
3. 2, 6 - Dichlorophenol-indophenol standard, 1 ml of dye equivalent to 0.1 mg of ascorbic acid.

Procedure.

Extraction

1. Equal weights of the sample and 6 per cent HPO_3 were blended to yield a heterogeneous slurry (300 gm. each).
2. Nitrogen was bubbled in the blender bowl through a glass tube under the surface of the liquid extractant for 15 to 30 seconds, before starting the blender, to minimize contact with atmospheric oxygen.

3. 30 to 40 gram of the slurry were weighed and transferred to a 100 ml volumetric flask and diluted to 100 ml with 3 per cent H.P.O.3. The weighing and dilution of the sample at this stage were made as rapidly as possible.
4. The diluted sample was filtered.

Titration.

25 ml of the filterate was titrated immediately with the standardized solution of 2, 6 - dichlorophenol-indophenol to a faint pink end paint which persists for 15 seconds.

Calculation.

The ascorbic acid was calculated according to the formula

$$\frac{V \times T}{W} \times 100 = \text{mg ascorbic acid per 100 grams sample.}$$

V = ml dye used for titration of aliquot of diluted sample.
T = ascorbic acid equivalent of dye solution expressed as mg per ml of dye.
W = grams of sample in aliquot titrated.

Indophenol-Xylene Extraction Method.

This procedure is based upon the quantitative decolorization of 2, 6 - dichlorophenolindophenol by ascorbic acid. (Pepkowitz (108)), (Robinson and Statz) (109). The excess of dye is extracted with xylene and measured by the absorbiometer.

Reagents:

1. Acetate Buffer ph.4.0 300 grams anhydrous sodium acitate mixed with 700 ml water and 1000 ml glucial acetic acid. Below a pH of 4.0 ascorbic acid oxidase is inhibited (Tauber, Kleiner, and Mishkind) (110) the dye is stable and the rate of reaction between ascorbic acid and the dye is maximum (Hockberg, Melnick and Oser) (111).

2. 2,6 - dichlorophenol-indophenol standard.

3. Xylene free from any oxidizing materials.

4. 6 per cent metaphosphoric acid.

5. Ascorbic acid standard.

Procedure:

Extraction

The same as in the visual titration method. The weighed sample was diluted to 100 ml with 6 per cent HPO_3 when filtered.

Reduction of Dye with Ascorbic Acid.

5 ml from the acid filterate of the sample was placed in a rubber stoppered test tube and 5 ml of the acetate buffer were added followed immediately with 3 ml dye solution and the mixture was shaken gently.

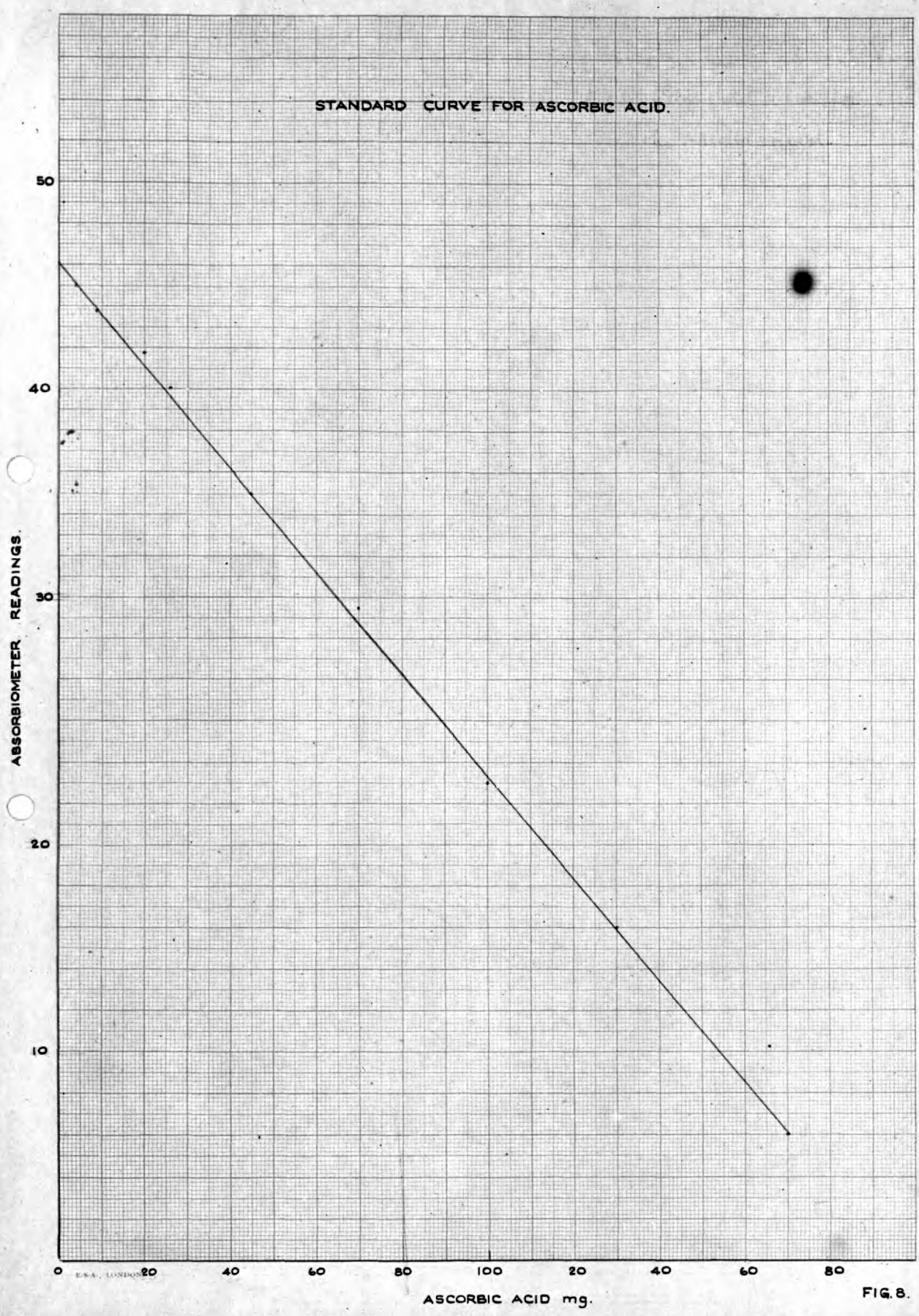

STANDARD CURVE FOR ASCORBIC ACID.
ABSORBIOMETER READINGS.
50
40
30
20
10
0
20
40
60
80
100
20
40
60
80
ASCORBIC ACID mg.

FIG. 8.

Extraction of Excess Dye with Xylene

10 ml xylene were added at once, the tube stoppered, and the mixture shaken vigorously for 6 to 10 seconds to extract excess dye then centrifuge briefly to separate the layers. The xylene layer was transferred to the absorbiometer cells by removing the aqueous layer with a pipet.

Standard ascorbic acid dilutions were prepared and a calibration curve was plotted fig (8).

RESULTS AND DISCUSSION

Ascorbic Acid Content of Different Varieties of Onions

During the season 1951 the ascorbic acid content of different varieties was estimated. The results are represented in Table (19).

From Table (19) it can be seen that the ascorbic acid content of the varieties varied remarkably. The variety Jaune de Lescure had the highest value 97.24 mg/100 gm and the variety Up to date showed the lowest value of 35.57 mg per 100 gm. Since the varieties studied during the season 1951 were not grown under the same conditions, the variations of the ascorbic acid, between the varieties, cannot be mainly due to genetic factors alone. The different conditions under which the varieties were grown

TABLE (19) ASCORBIC ACID CONTENT OF DIFFERENT VARIETIES OF ONIONS. (DRY BASIS)

1951		Grown in Harlington 1952	
Variety	Ascorbic Acid	Variety	Ascorbic Acid
English Varieties	mg/100g.	English Varieties	mg/100g
Alisa Craig 1/	88.5	Prizetaker	64.35
Southport Yellow Globe	72.39	Density	60.29
Up to Date	35.57	Best of All	56.08
Best of All	50.54	Giant Zittau	54.45
White Spanish	47.76	A.I.	56.23
Giant Zittau 1/	59.64	Walker's Exhibition	54.27
Giant Zittau 2/	47.04		
Bedfordshire Champion	80.32	French Varieties	
Red Zittau	68.00	Rose Garole	35.50
Dahneils Red Globe	88.61	de Moulhouse (bulb ronde)	45.86
Cambridge 10	67.11		
Alisa Craig 2/	62.41	Rouge pale de Niort	54.46
Monarch	68.16		
* French Varieties			
de Moulhouse (bulbs flat)	51.08	de Moulhouse (bulbs flat)	38.88
Rouge fonce	68.46	Rouge fonce	35.90
Jaune de Saint Michel	56.48	Jaune de Saint Michel	46.57
Jaine Palle des Vertus	61.48	Jaune Palle des Vertus	47.06
Jaine de Lescure	97.24	Jaine de Lescure	60.40
* Giza 6 (Egyptian Variety)	89.03	Giza 6 (Egyptian Variety)	38.45

* Imported from France and Egypt.

might have great effect on the ascorbic acid content of the varieties. This observation can best be seen from the case of the two varieties Alisa Craig and Giant Zittau. Two samples from each variety were brought from different firms. The difference in the ascorbic acid content within the variety itself can be easily seen. Alisa Craig 1. had an ascorbic acid content of 85.5 mg. per 100 gm. while Alisa Craig 2 contained 62.44 mg per 100 gm. Giant Zittan 1 and 2 had an ascorbic content of 59.64 mg per 100 gm. and 47.04 mg per 100 gm. respectively. This remarkable variation in the ascorbic acid content within the variety itself might largely be due to the different weather and soil conditions under which each sample of the same variety was grown.

During the 1952 season different varieties were grown in Harlington, and their ascorbic acid content was determined. Although the varieties were grown under the same conditions, they varied considerably in their ascorbic acid content. Prizetaker was the variety with the highest ascorbic acid content which was 64.35 mg. per 100 gm. whilst Rose Carole showed the lowest value of 35.50 mg. per 100 gm.

Comparing the results obtained in the two seasons it is obvious that the difference in the ascorbic acid amongst the varieties in the season 1953 was much greater than that of the 1952. The ascorbic acid content of the different

varieties ranged from 35.57 to 97.24 mg. per 100 gm. in 1951 whilst it ranged from 35.50 to 64.35 mg per 100 gm. in 1952.

The outstanding point in Table (19) is the difference in the ascorbic acid content of the French and Egyptian varieties imported in 1951, and of the same varieties grown in Harlington in 1952. It can be seen that all the varieties showed a considerable decrease in their ascorbic acid content when grown in Harlington than the imported samples in 1951. The Egyptian variety, Giza 6, showed the biggest decrease when grown at Harlington. The French variety Jaune de Lescure, when imported from France, showed the highest ascorbic acid content, and although when grown at Harlington it decreased considerably, it was still the variety with the highest ascorbic acid content.

From the above data it can be seen that there is a definite variation in the ascorbic acid of the different varieties when grown under the same conditions.

Also the growing conditions seem to be an important factor in the synthesis of the ascorbic acid in the onion bulb.

EFFECT OF GROWTH ON THE ASCORBIC ACID CONTENT OF THE ONION

The ascorbic acid content was estimated in different varieties of onions grown at Harlington during the season 1952 at different stages of maturity.

The results tabulated in Table (20) show the changes in the ascorbic acid content of the different varieties throughout the growth of the plant. It can be seen that the ascorbic acid of all the varieties had the same behaviour throughout the maturity stages. The ascorbic acid decreased from the start till the plant reached maturity. When the results are presented graphically Fig. (9) it can be observed that as the onion approaches and reaches maturity its ascorbic acid decreased. The outstanding point which can be seen from Table (20) and Fig (9) is that all the varieties showed a very sharp decrease into the ascorbic acid during the second sampling followed by a gradual decrease till the plant reached maturity.

It can also be seen that the varieties differed greatly in their ascorbic acid content during the first sampling, the differences became very much smaller during the second sampling and so till the plant reached maturity.

While the ascorbic acid decreased throughout the growth of the plant, the bulbs at the same time were growing

TABLE 20) ASCORBIC ACID CONTENT OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH (DRY BASIS)

Variety	Ascorbic Acid Content (mg.per 100 g.)				
	Age in Weeks				
	12	14	17	20	23
St.Michel	197.17	74.77	56.62	52.56	46.57
des Vertus	213.52	82.63	71.94	60.69	47.06
Rose Garole	167.28	66.84	50.88	45.37	35.50
Moulhouse (ronde)	178.77	74.94	59.58	48.64	45.86
Rouge Fonce	178.77	66.80	48.35	40.76	35.9
Rouge Niort	314.40	75.20	65.20	57.90	54.46
Lescure	328.30	86.95	70.60	70.76	60.40
Moulhouse (flat)	145.19	81.73	53.50	45.75	38.88
Giza 6	115.7	62.74	47.30	42.83	38.45

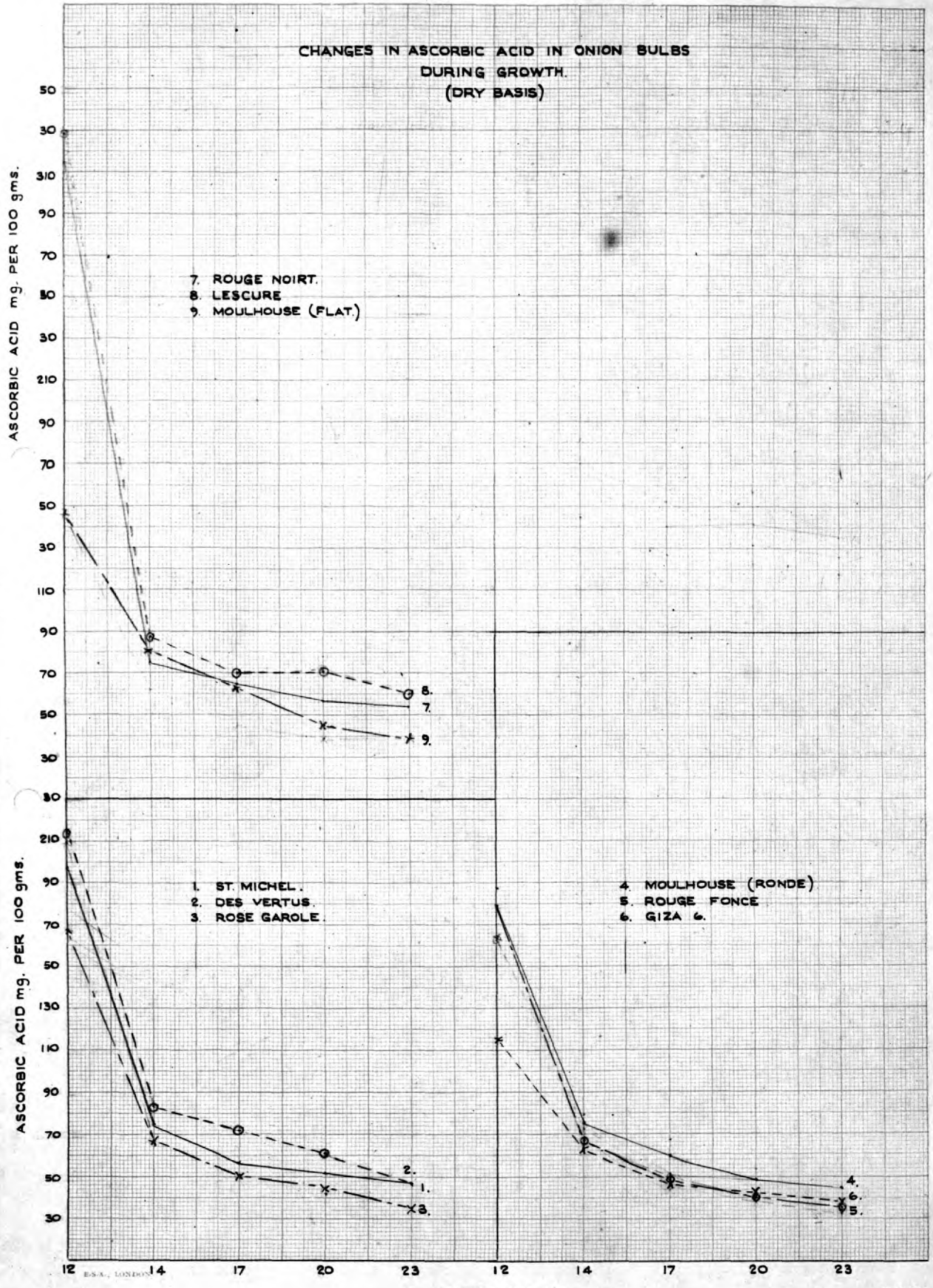

CHANGES IN ASCORBIC ACID IN ONION BULBS
DURING GROWTH.
(DRY BASIS)
ASCORBIC ACID mg. PER 100 gms.
7. ROUGE NOIRT.
8. LESCURE
9. MOULHOUSE (FLAT.)
8.
7.
9.
ASCORBIC ACID mg. PER 100 gms.
1. ST. MICHEL.
2. DES VERTUS.
3. ROSE GAROLE.
4. MOULHOUSE (RONDE)
5. ROUGE FONCE
6. GIZA 6.
2.
1.
3.
4.
6.
5.
12
14
17
20
23
AGE IN WEEKS.

FIG. 9.

larger in size. The rapid decrease in the ascorbic acid at the early stage was accompanied by a rapid increase in the seize of the bulb. As the plant approached maturity the decrease in the ascorbic acid became very much less than that in the early stage and the growth of the bulb became slower. The bulb of the onion, at the early stages of the growth, contained a high proportion of the young and active tissues, and, as the bulb grew further the active tissue became less as a result of the formation of outer storage tissues.

It was reported by Murphy (62) that onions which exhibited a high average concentration of ascorbic acid consisted of a large proportion of small onions. Conversely the onions which were lower in ascorbic acid were preponderantly larger in size. The same Author (62) also reported that the highly active immature tissue in the exact centre of the bulb is the most potent section of the onion bulb when considering ascorbic acid, the outer leaves containing much less.

Accordingly it seems that the size of the bulb, and the consequent increase in proportion of the outer tissues, as compared with the inner tissue, is an influencing factor to this phenomenon. The physiological age of the tissue

whether expressed as maturity, size of the bulb, or proportion of more highly active inner tissue to less active outer tissue, is likely to determine, to a larger degree, the ascorbic acid content at any given time.

EFFECT OF STORAGE ON THE ASCORBIC ACID CONTENT OF THE ONION

The changes in the ascorbic acid content of the different varieties of onions during three months of storage are shown in Table (21).

It can beseen from the results that all the varieties lost a considerable amount of their ascorbic acid during the storage period. The results in Table (21) and Fig. (10) also indicate that the biggest decrease in the ascorbic acid occurred after the first month of storage. This was the case for six of the ~~nine~~ seven varieties, Rose Garole, Rouge fonce, Rouge pale de Niort and Moulhouse (bulbs flat). On the other hand the varieties Jaune paille de Vertus and de Moulhouse (bulbes ronde) showed the biggest loss during the third month of storage. During the second month of storage although all the varieties decreased in their ascorbic acid content, the varieties Moulhouse (bulbs flat) did not change in the ascorbic acid content then decreased again during the third month.

TABLE(21) EFFECT OF STORAGE ON ASCORBIC ACID CONTENT OF ONIONS

Variety	Content after harvest	After 1 mth's storage	Amount lost during storage		After 2 mth's storage	Amount lost during storage		After 3 mth's storage	Amount lost during storage	
	mg/100gm.	mg/100gm.	mg/100gm.	percent.	mg/100gm.	mg/100gm.	per cent.	mg/100gm.	mg/100	per cent
St.Michel	46.75	43.00	3.75	8.0	40.83	5.92	12.7	36.81	9.94	21.3
des Vertus	47.06	42.95	4.11	8.7	39.17	7.89	16.8	30.93	16.13	34.3
Rose Garole	35.50	23.39	12.11	34.1	21.94	13.56	38.1	18.25	17.25	48.6
Moulhouse (ronde)	45.86	41.56	4.32	9.4	38.99	6.87	14.9	30.51	15.35	33.5
Rouge fonce	35.90	29.52	6.38	17.8	23.28	12.64	35.2	20.77	15.13	42.1
Rouge Niort	54.46	37.21	17.25	31.7	31.05	23.41	42.9	27.22	27.24	50.0
Moulhouse (flat)	38.88	30.68	8.20	21.1	31.14	7.74	19.9	26.33	12.55	32.3

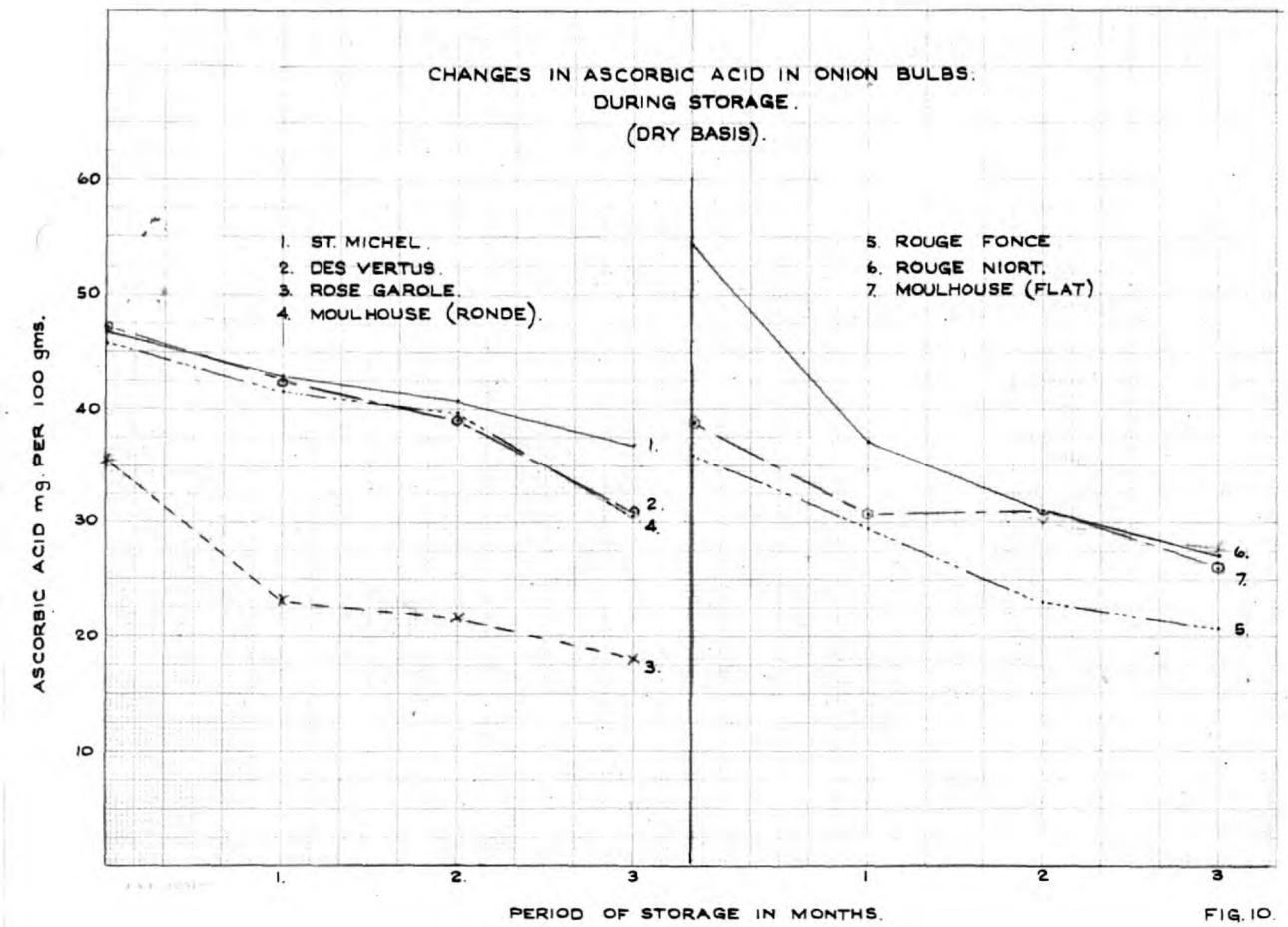

CHANGES IN ASCORBIC ACID IN ONION BULBS.
DURING STORAGE.
(DRY BASIS).
1. ST. MICHEL.
2. DES VERTUS.
3. ROSE GAROLE.
4. MOULHOUSE (RONDE).
5. ROUGE FONCE
6. ROUGE NIORT.
7. MOULHOUSE (FLAT)
ASCORBIC ACID mg. PER 100 gms.
60
50
40
30
20
10
1.
2.
3
1
2
3
PERIOD OF STORAGE IN MONTHS.

FIG. 10.

It can be seen also from table (21) that the losses after the first month of storage ranged from 8.0 to 34.1 per cent, 12.7 to 38.1 per cent after the second month of storage and 21.3 to 50.0 per cent at the end of the storage period.

The above data indicates that a drastic reduction of ascorbic acid occurred in onions throughout storage.

Murphy (62) reported that under normal storage conditions onions lost from 47 to 80 per cent of their ascorbic acid which is very much in agreement with the results obtained in this work.

C H A P T E R VII

STUDIES ON THE SUGAR CONTENT OF ONIONS.

Method of Analysis

Twenty bulbs from each sample were used for the determination of sugars. The bulbs outer dead layers were peeled and ground with a food chopper. After mixing the sample, 20 to 40 grams were weighed accurately for the analysis.

Extracting The Sugars From The Tissue

A blender was used for comminuting the weighed portions of the samples, in the presence of distilled water, which was used as an extracting solvent. Small amounts of calcium carbonate were added to the samples, before they were blended, to neutralize the plant acids. The samples were blended for 10 minutes.

Filtering The Extracts

All filtrations were made with Buchner funnels using suction. Discs cut from filter cloth were used for filtering the extracts. The container of the blender was washed carefully to ensure the complete transfer of the samples to the funnels.

Evaluating The Amounts of Sugars In The Filtered Extracts

The extracts were transferred quantitatively to volumetric flasks. The protein was precipitated from the extracts with lead acetate. The excess of lead was removed with potassium oxalate.

Separate aliquots were hydralyzed with 6.5 normal hydrochloric acid at 70°c for eight minutes for the determination of the total sugars.

The amount of reducing sugars and total sugars present were evaluated by Lane - Eynon volumetric method (112).

RESULTS AND DISCUSSION

The Effect of Growth

The Sugar Content of The Onion

The results of the total sugars of the different varieties of onions at different stages of maturity are represented in Table (22) and illustrated in Fig. (11). From the Table and the curves the different varieties can be divided into three groups. The first group includes the varieties which reached their maximum total sugar content during the third sampling. These varieties were St. Michel, Rose de Carole, Rouge de Niort, Lescure and Moulhouse (bulb flat). The changes in the total sugars of this group were characteristic of three stages. The first, a rapid increase from the first date of sampling to the second, followed by a gradual increase till the varieties

TABLE (22) TOTAL SUGAR CONTENT OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH (DRY BASIS)

Variety	Total Sugars per cent				
	Age in Weeks				
	12	14	17	20	23
St. Michel	46.2	59.8	64.0.	58.6	61.8
des Vertus	48.3	60.8	68.5	73.8	62.1
Rose Carole	39.0	54.9	63.9	59.8	59.8
Moulhouse (ronde)	54.3	67.3	62.9	61.1	61.8
Rouge Fonce	34.0	65.7	61.3	61.8	64.4
Rouge Niort	43.5	55.5	67.8	54.1	56.7
Lescure	48.8	61.6	65.9	62.4	60.8
Moulhouse (flat)	59.9	66.2	66.8	64.4	64.7
Giza 6	44.0	62.1	61.0	60.3	61.6

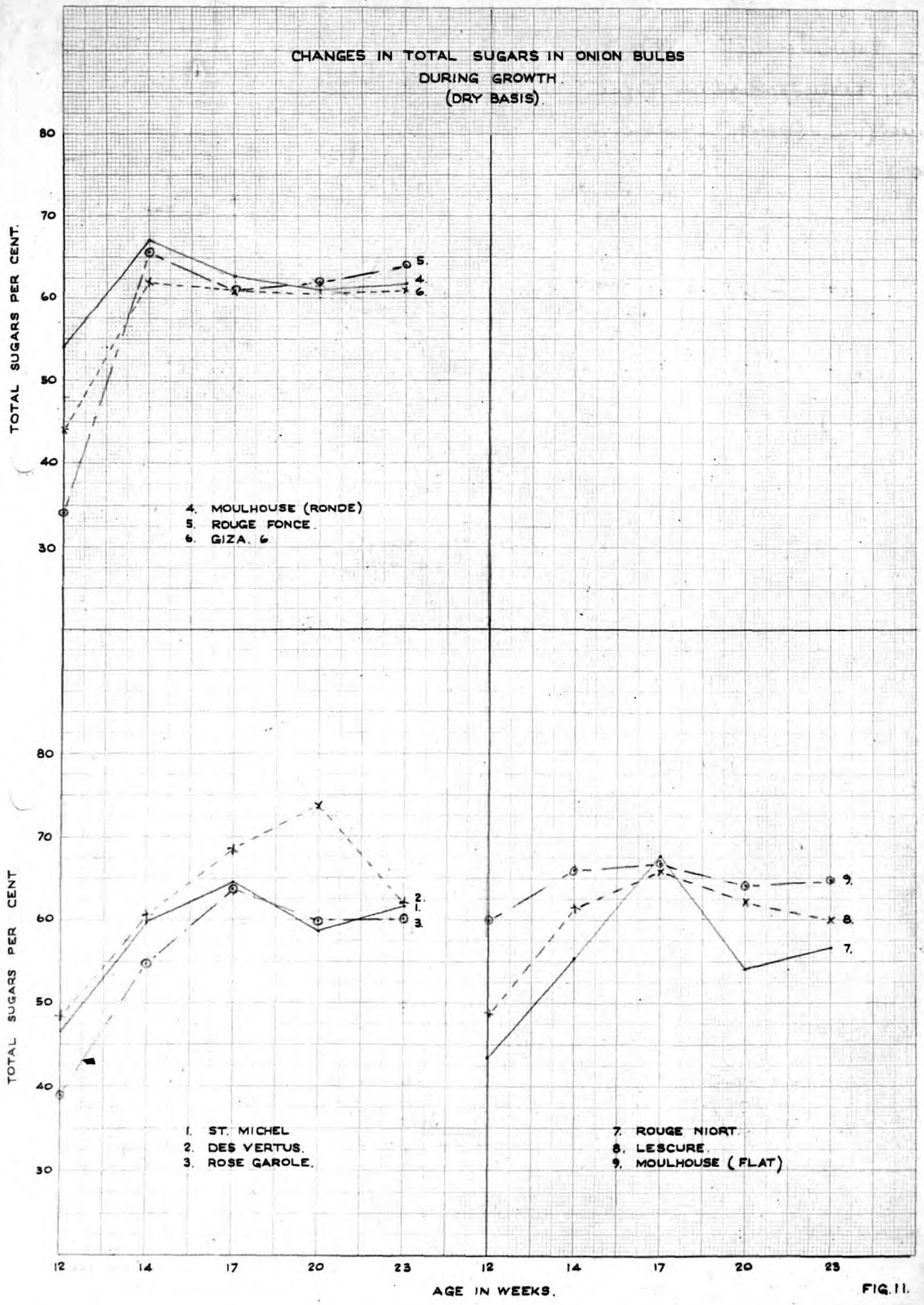

CHANGES IN TOTAL SUGARS IN ONION BULBS
DURING GROWTH.
(DRY BASIS).
TOTAL SUGARS PER CENT.
80
70
60
50
40
30
5.
4.
6.
4. MOULHOUSE (RONDE)
5. ROUGE FONCE.
6. GIZA. 6
TOTAL SUGARS PER CENT
2.
1.
3.
1. ST. MICHEL
2. DES VERTUS.
3. ROSE GAROLE.
9.
8.
7.
7. ROUGE NIORT.
8. LESCURE.
9. MOULHOUSE (FLAT)
12
14
17
20
23
AGE IN WEEKS.

FIG. 11.

reached its maximum sugar content during the third sampling. The third stage was a gradual decrease until the plants reached maturity. This was the general trend of the first group with the exception of the variety Rouge de ~~Noire~~ Niort which showed a rapid increase till the third sampling followed by a very rapid decrease in the total sugar towards maturity.

The second group includes the varieties Moulhouse (bulbs ronde) Rouge Ponce and Giza 6 where their total sugars were reached during the second sampling. The changes in the total sugars of these varieties can be divided into two stages, a rapid increase, during which the varieties reached their maximum total sugar content during the second sampling, followed by a gradual decrease, until the plants reached maturity.

The third group which reached their maximum total sugar content during the fourth sampling includes the variety Des Vertus. A sharp increase is noticeable towards the fourth sampling then a sharp decrease until the plant reached maturity.

It can be seen from the curves that the varieties differed considerably in the degree of increase and decrease throughout their growth. When the plants matured, the difference in the total sugar content for all the varieties

became rather smaller and ranged from 56.7 to 64.7 per cent. It is obvious,however, that the total sugars were the chief component of the dry matter indicating that the dry matter and the total sugars are related to each other.

Since the total sugars consist of non reducing and reducing sugars it was important to study the changes of each of these components separately during the growth of the plant.

The changes in the non reducing sugars are presented in Table (23) and illustrated in fig. (12). Five of the varieties showed a rapid increase in the non reducing sugars until the third sampling,then decreased gradually until maturity. The varieties were St. Michel, Rose Carole, Rouge de ~~Nolet~~ Niort, Lescure and Moulhouse (bulbs flat). The varieties Moulhouse (bulbs ronde) and Giza 6 increased rapidly in their non reducing sugar content until the second sampling then decreased gradually towards maturity. The variety des Vertus increased rapidly until the fourth sampling then decreased until it reached maturity. On the other hand the variety Rouge Fonce did not show any decline in the non reducing sugar throughout the growth.

From the Table it can be seen that the non reducing sugar content varied considerably between the varieties which can be divided into three groups according to their non reducing sugar content. The first group contains the

T A B L E (23) NON REDUCING SUGARS CONTENT OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH (DRY BASIS)

Variety	Non Reducing Sugars per cent				
	Age in weeks				
	12	14	17	20	23
St. Michel	24.9	42.4	50.7	41.3	41.7
des Vertus	25.8	41.2	46.1	51.6	38.3
Rose Garole	22.6	41.3	58.8	49.6	48.9
Moulhouse (ronde)	33.5	54.2	50.9	47.7	44.4
Rouge Fonce	15.4	48.9	49.2	53.2	52.9
Rouge Niort	21.3	34.2	45.9	34.3	31.5
Lescure	10.2	25.2	28.4	11.7	8.7
Moulhouse (flat)	33.9	46.8	56.9	52.5	44.8
Giza 6	25.1	47.4	46.6	33.2	40.3

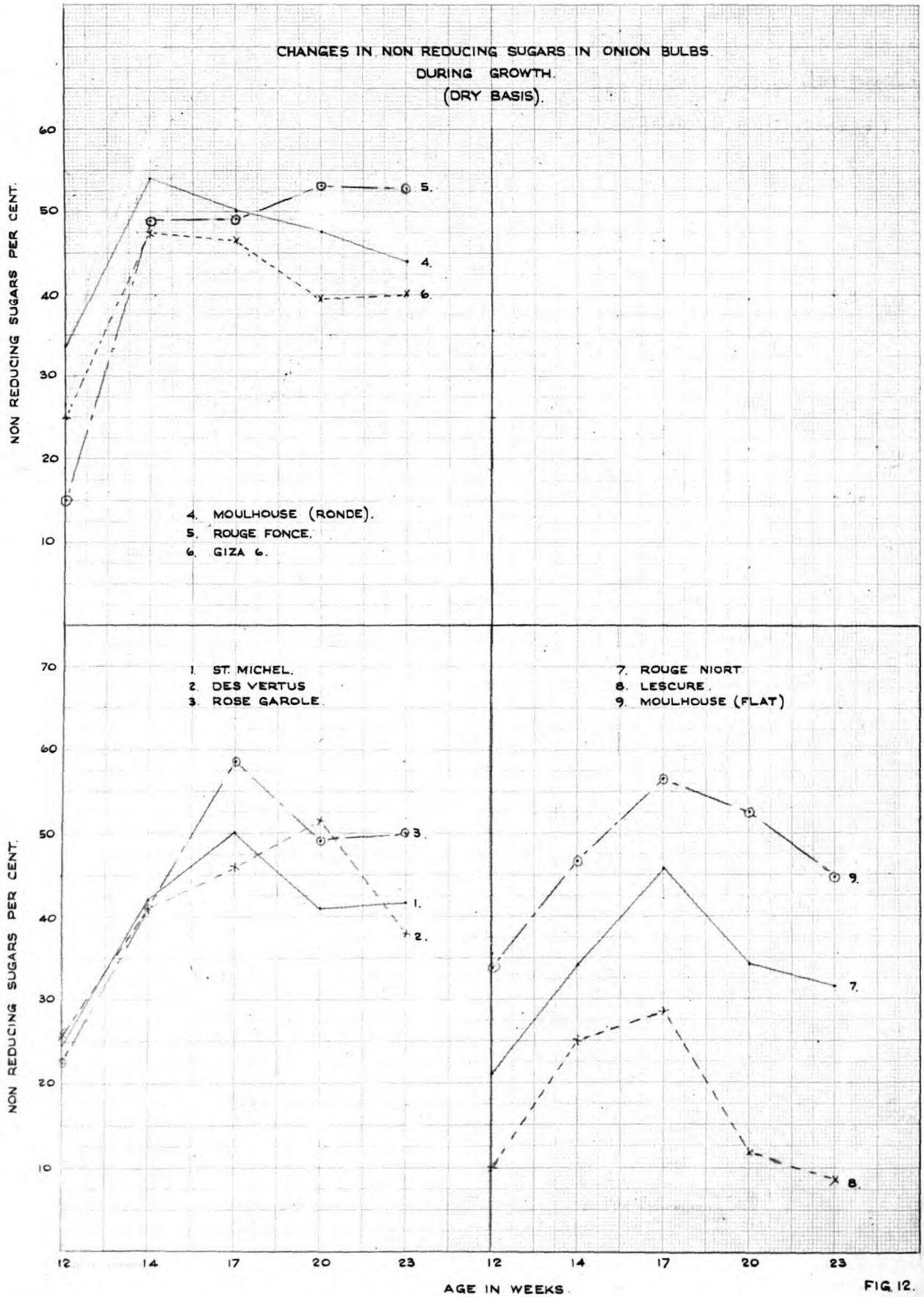

CHANGES IN NON REDUCING SUGARS IN ONION BULBS
DURING GROWTH.
(DRY BASIS).
NON REDUCING SUGARS PER CENT.
60
50
40
30
20
10
5.
4.
6.
4. MOULHOUSE (RONDE).
5. ROUGE FONCE.
6. GIZA 6.
1. ST. MICHEL.
2. DES VERTUS
3. ROSE GAROLE.
7. ROUGE NIORT
8. LESCURE.
9. MOULHOUSE (FLAT)
70
60
50
40
30
20
10
3.
1.
2.
9.
7.
8.
12
14
17
20
23
AGE IN WEEKS.

FIG. 12.

varieties with the highest non-reducing sugar content. These are : Rose Garole, and Rouge fonce. Their non-reducing sugar content was 48.9 and 52.9 per cent respectively. The second group with a lower percentage of non-reducing sugar comprises St. Michel, des Vertus, Moulhouse (bulbs ronde) Rouge de ~~Niort~~ Niort, Moulhouse (bulbs flat) and Giza 6. The non reducing sugar content for these varieties was 41.5, 38.3, 44.4, 51.5, 44.8 and 40.2 respectively. The third group, with the lowest percentage of non reducing sugar, includes the variety Lescure which had a non reducing sugar content of 8.7 per cent.

A great similarity in the changes of the non-reducing sugar and the total sugars can be observed.

It is important to note that the non-reducing sugar is the chief component of the total sugar and is mainly responsible for the changes in the latter. There is a close relationship between non-reducing and total sugars throughout growth. Lescure had a non-reducing sugar content of 8.7 per cent; it is obvious that the reducing sugar was the chief component of the total sugars which accounts for the difference in behaviour between the changes of the non-reducing and total sugars, for this particular variety, during the maturity stages.

Studying the changes of the reducing sugar content throughout the growth of the plant, Table (24) fig. (13) represents the results obtained during the Season 1952. The reducing sugar content of all the varieties decreased until they reached their lowest values then increased again towards maturity. Fig. (13) indicates that the lowest percentage sugar was reached at varying times by different varieties but the majority of these behaved in the same way, in that their reducing sugars reached the lowest values during the third sampling, then increased again towards maturity. It is interesting to note that the variety Lescure showed a slight decrease, from the first sampling towards the third, then increased rapidly in the reducing sugar until it matured. On the other hand the variety des Vertus showed a slight change in the reducing sugar throughout the growth.

When the bulbs matured it can be seen from Table (24) that some varieties had a relatively low percentage of reducing sugar content while others had a relatively high percentage. The varieties Rose Carole and Rouge Ponce had the lowest reducing sugar content of 10.9, and 11.5 per cent respectively. It is important to note that these three particular varieties showed the highest values for the non-reducing sugar. Lescure, the variety with the lowest non-

T A B L E (24) REDUCING SUGARS CONTENT OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH (DRY BASIS)

Variety	Reducing Sugars per cent				
	Age in Weeks				
	12	14	17	20	23
St. Michel	21.9	17.4	13.3	17.3	20.1
des Vertus	22.5	19.6	22.4	22.2	23.8
Rose Garole	16.4	13.6	5.1	10.2	10.9
Moulhouse (ronde)	20.8	15.1	12.0	13.4	17.4
Rouge Fonce	18.6	16.8	12.1	8.6	11.5
Rouge Niort	22.2	21.5	21.9	19.8	25.2
Lescure	38.6	36.4	37.5	50.7	52.1
Moulhouse (flat)	26.0	19.4	9.9	11.9	19.9
Giza 6	18.9	14.7	14.4	21.1	21.3

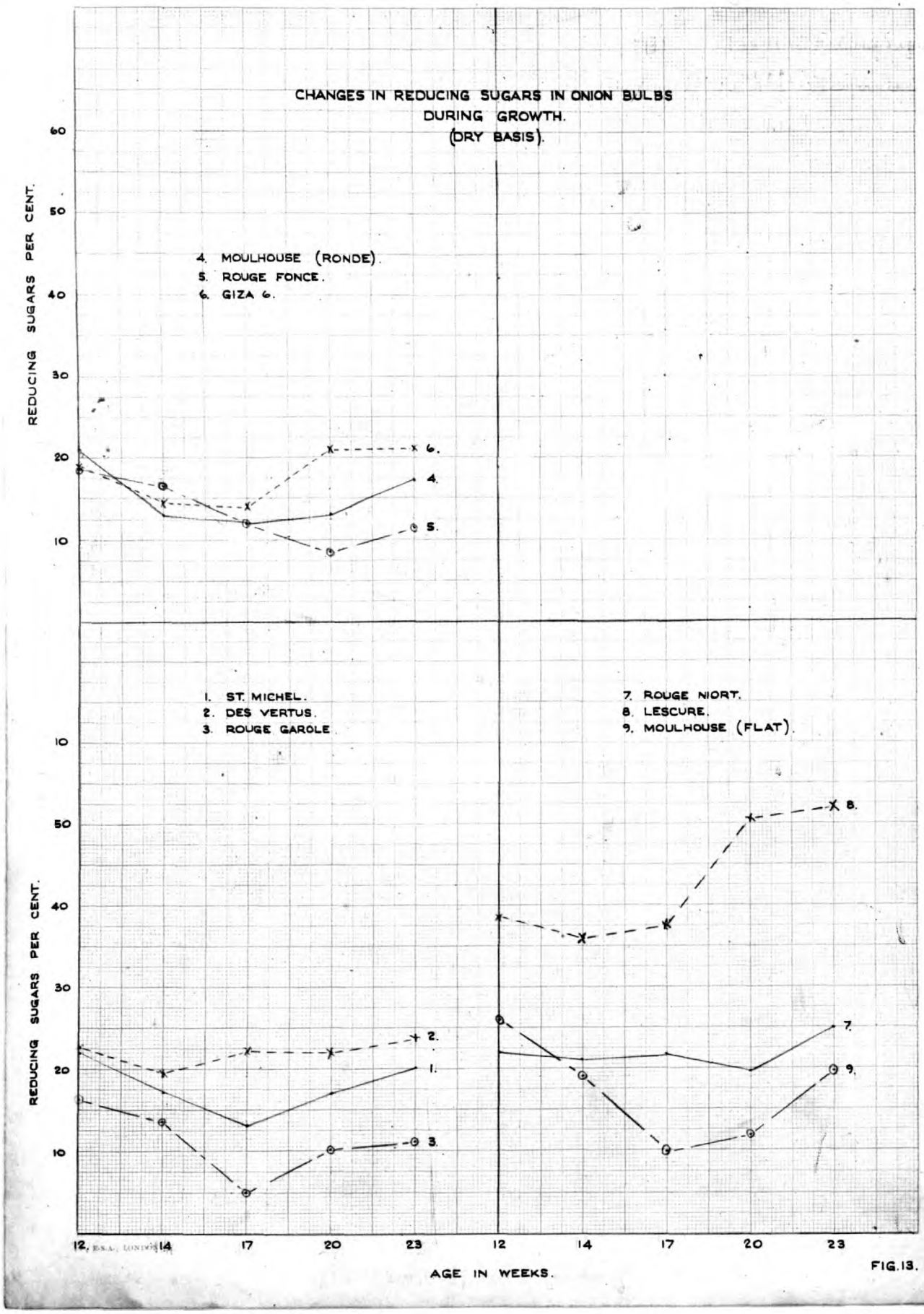

CHANGES IN REDUCING SUGARS IN ONION BULBS
DURING GROWTH.
(DRY BASIS).
REDUCING SUGARS PER CENT.
60
50
40
30
20
10
4. MOULHOUSE (RONDE).
5. ROUGE FONCE.
6. GIZA 6.
6.
4.
5.
1. ST. MICHEL.
2. DES VERTUS.
3. ROUGE GAROLE.
7. ROUGE NIORT.
8. LESCURE.
9. MOULHOUSE (FLAT).
8.
7.
9.
2.
1.
3.
12
14
17
20
23
AGE IN WEEKS.

FIG. 13.

reducing sugar content, had the highest reducing sugar content of 52.1 per cent.

Comparing the changes of the reducing sugar with that of the non reducing sugar throughout the growth of the plant, the two components behaved inversely to each other. While the non-reducing sugar increased, a corresponding decrease occurred to the reducing sugar and vice-versa. It is important to note that the changes in the non-reducing sugar were much greater than the changes in the non-reducing sugar. This difference in the behaviour of the reducing sugar, to that of the total sugars and the non-reducing sugar, is clearly illustrated in Fig. (14) which represents the mean values of every component at the same date of sampling. The curves show the great similarity in the changes of the total sugars and the non-reducing sugars in the onion as a whole, regardless of the individual varieties.

The comparison of the non-reducing sugar and the reducing sugar content of the onion, shows that the former always exceeded the latter except in the variety Lescure where the reducing sugar exceeded the non-reducing sugar. Bennett (90) reported that under optimum conditions the reducing sugars constitute only a small percentage of the total soluble sugars, but in this investigation the reducing was higher.

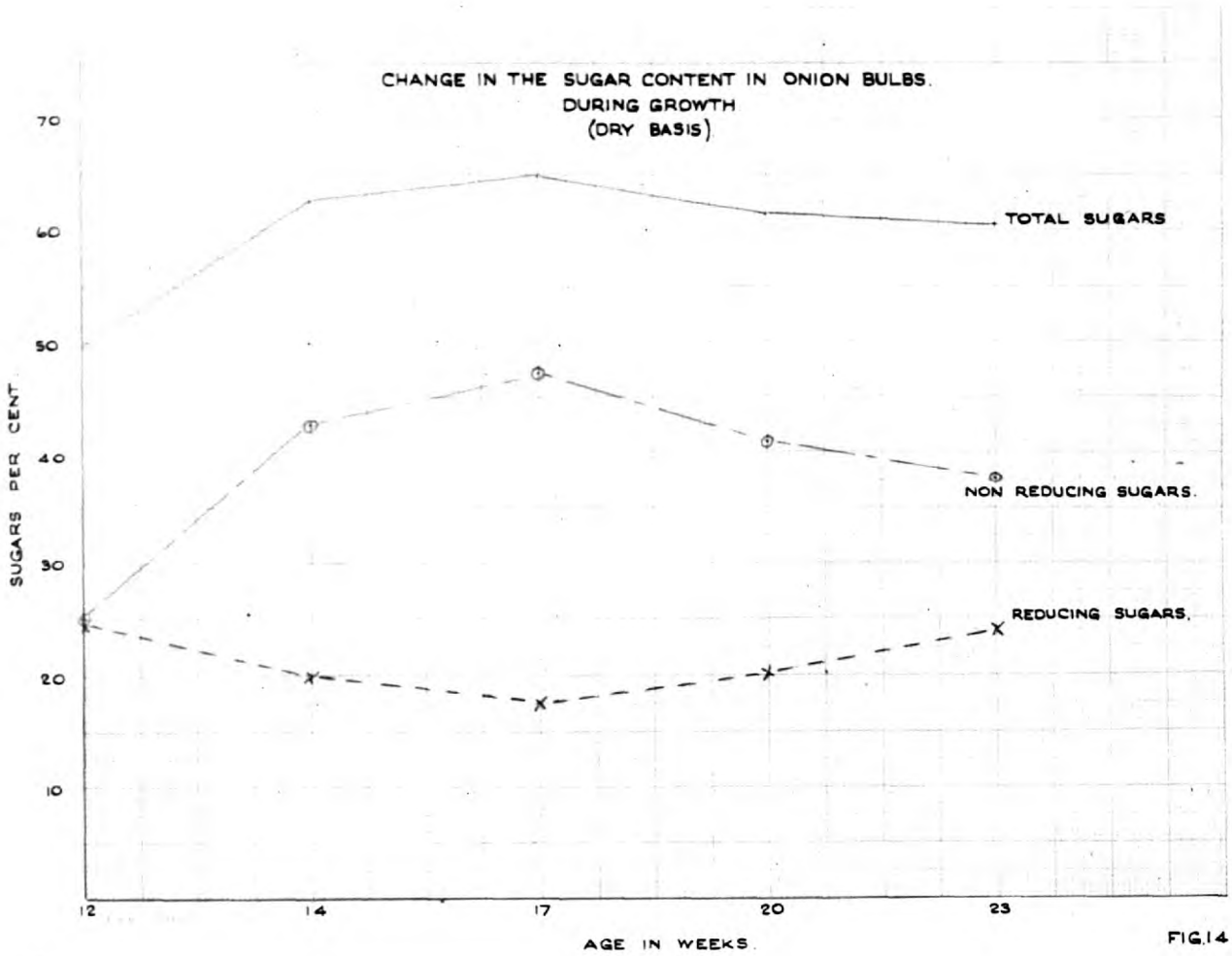

CHANGE IN THE SUGAR CONTENT IN ONION BULBS.
DURING GROWTH
(DRY BASIS)
SUGARS PER CENT.
70
60
50
40
30
20
10
TOTAL SUGARS
NON REDUCING SUGARS.
REDUCING SUGARS.
12
14
17
20
23
AGE IN WEEKS.

FIG.14.

The relationship between the reducing and non-reducing sugar can be clearly presented by the monosaccharides/disaccharides ratio Table (25). The ratio for all the varieties was less than 1, except for the variety Lescure, throughout the growth of the plant. This indicates that during the different stages of maturity the non-reducing sugars exceeded the reducing sugar. The Table also indicates that the ratio decreased until it reached its lowest value, then increased again towards maturity, which was attained during the third sampling for the majority of the varieties. ~~In other words, when the ratio was at its lowest value.~~ The behaviour of the ratio during the growth of the plant points out clearly that the non-reducing and reducing sugars were changing in the opposite direction to each other.

THE EFFECT OF STORAGE ON THE SUGAR CONTENT OF DIFFERENT VARIETIES OF ONIONS.

The determination of sugar content in this experiment was carried out monthly. Table (26) represents the results of the total sugar content of different varieties of onions during the storage period of three months.

The varieties showed a decrease in the total sugar content throughout the storage period. These changes can

T A B L E (25) MONOSACCHARIDES/DISACCHARIDES RATIO OF DIFFERENT VARIETIES OF ONIONS DURING GROWTH

Variety	Monosaccharides/Disaccharides Ratio				
	Age in Weeks				
	12	14	17	20	23
St. Michel	0.88	0.41	0.26	0.42	0.48
des Vertus	0.88	0.48	0.49	0.43	0.62
Rose Garole	0.73	0.33	0.09	0.21	0.22
Moulhouse (ronde)	0.62	0.24	0.24	0.28	0.39
Rouge Fonce	1.21	0.34	0.25	0.16	0.22
Rouge Niort	1.04	0.62	0.48	0.58	0.80
Lescure	3.76	1.4	1.32	4.32	5.99
Moulhouse (flat)	0.77	0.41	0.17	0.237	0.45
Giza 6	0.76	0.31	0.31	0.54	0.53

T A B L E (26) EFFECT OF STORAGE ON THE TOTAL SUGARS OF DIFFERENT VARIETIES OF ONIONS (DRY BASIS)

Variety	Total Sugars (per cent)				Per Cent loss in Total Sugars
	After harvest	1st Month	2nd Month	3rd Month	
St. Michel	61.8	57.4	56.3	52.6	14.7
des Vertus	62.1	55.2	53.2	50.0	19.4
Rose Carole	59.8	54.4	51.5	51.2	14.5
Moulhouse (ronde)	61.8	58.6	56.5	53.8	12.8
Rouge Fonce	64.4	60.1	58.6	57.2	11.2
Rouge Niort	56.7	55.3	54.6	51.3	9.5
Moulhouse (flat)	64.7	61.5	59.7	57.5	11.1

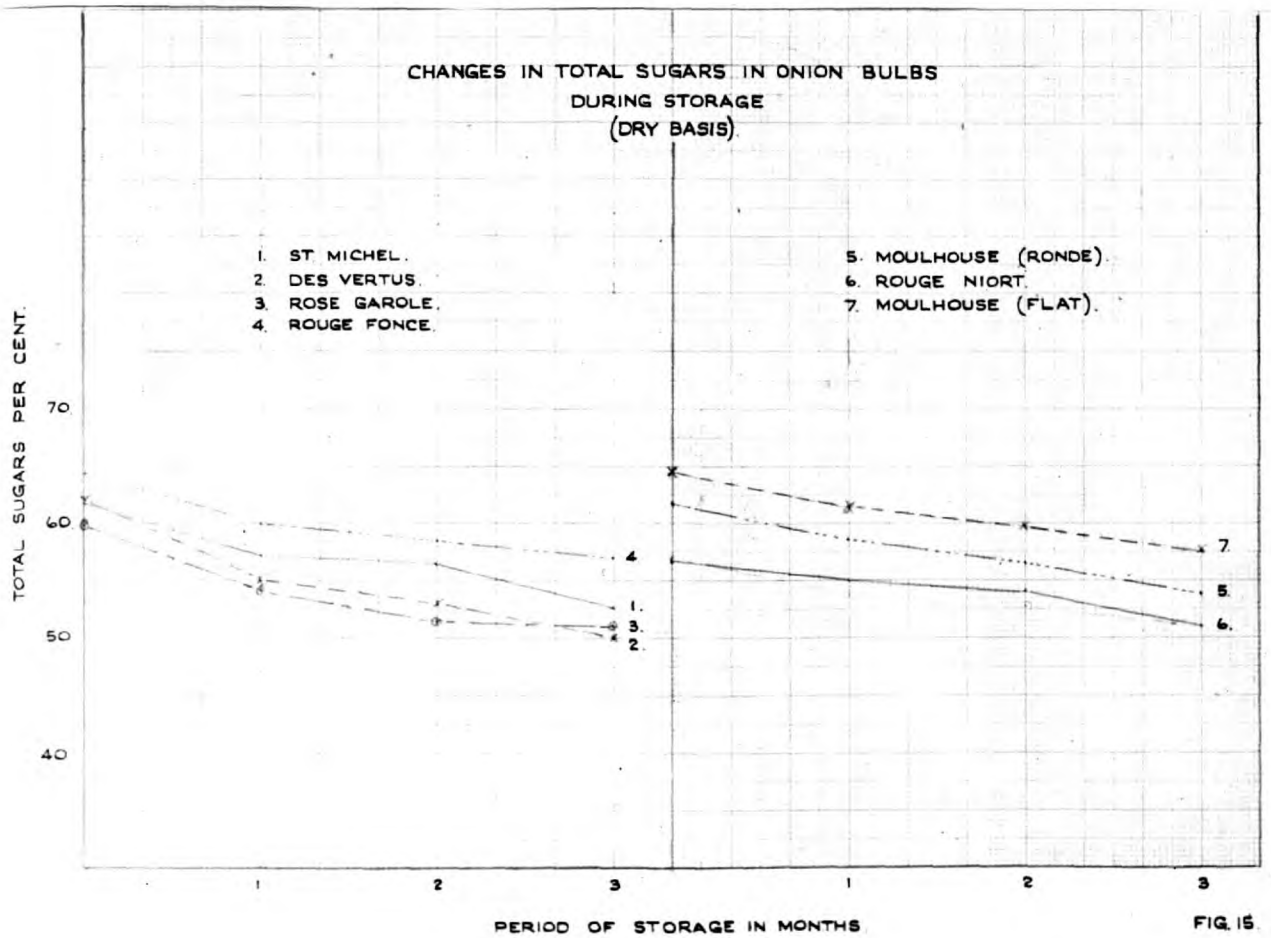

CHANGES IN TOTAL SUGARS IN ONION BULBS
DURING STORAGE
(DRY BASIS)
1. ST. MICHEL.
2. DES VERTUS.
3. ROSE GAROLE.
4. ROUGE FONCE.
5. MOULHOUSE (RONDE).
6. ROUGE NIORT.
7. MOULHOUSE (FLAT).
TOTAL SUGARS PER CENT.
70
60
50
40
1
2
3
1
2
3
PERIOD OF STORAGE IN MONTHS

FIG. 15

be seen from the curves in fig (15) which illustrates the behaviour of the total sugars during storage. Although all the varieties were stored under the same conditions, the loss in total sugars varied considerably between the varieties. While the variety Rouge de Niort lost 9.5 per cent of its total sugar content at the end of the storage period, variety des Vertus lost 19.4 per cent.

Since the non-reducing sugars were the main componnent of the total sugars, their changes during storage are an important study.

The changes in the non-reducing sugars during storage are shown in Table (27). The results indicate that the non-reducing sugars decreased remarkably during the whole period of storage. This was the case for all the Varieties. Fig. (16) shows the remarkable change in the non-reducing sugars compared with that of the total sugars. This difference can be detected from the comparison between the percentage loss of the non-reducing sugars and the total sugars at the end of the storage period. While the percentage loss for the former ranged from 33.6 to 70.0 per cent, it was from 9.5 to 19.1 per cent for the latter.

On the other hand the reducing sugars changed quite oppositely to the non-reducing and total sugars. All

T A B L E (27) EFFECT OF STORAGE ON THE NON REDUCING SUGARS OF DIFFERENT VARIETIES OF ONIONS (DRY BASIS)

Variety	Non Reducing Sugars (per cent)				Per cent loss in Non Reducing Sugars
	After harvest	1st Month	2nd Month	3rd Month	
St. Michel	41.7	33.7	25.5	20.7	50.2
des Vertus	38.3	26.4	22.5	19.0	50.3
Rose Garole	48.9	43.6	37.7	32.5	33.6
Moulhouse (ronde)	44.4	36.0	31.1	25.2	43.2
Rouge Fonce	52.9	40.0	36.4	29.7	43.9
Rouge Niort	31.5	25.7	18.4	11.6	63.3
Moulhouse (flat)	44.8	39.2	31.9	23.8	64.7

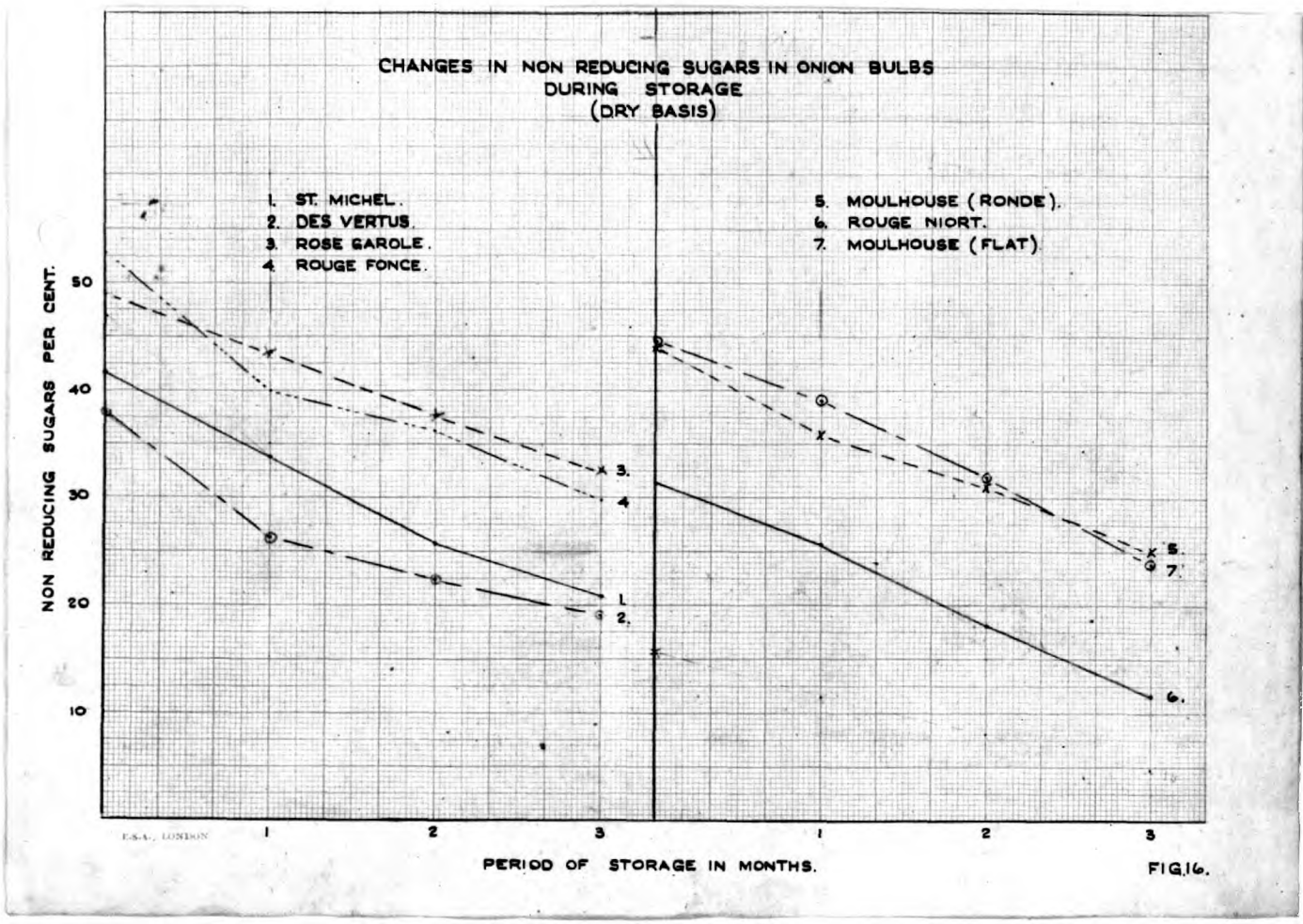

CHANGES IN NON REDUCING SUGARS IN ONION BULBS
DURING STORAGE
(DRY BASIS)
1. ST. MICHEL.
2. DES VERTUS.
3. ROSE GAROLE.
4. ROUGE FONCE.
5. MOULHOUSE (RONDE).
6. ROUGE NIORT.
7. MOULHOUSE (FLAT).
NON REDUCING SUGARS PER CENT.
50
40
30
20
10
1
2
3
1
2
3
PERIOD OF STORAGE IN MONTHS.

FIG.16.

varieties showed increases in their reducing sugar content as shown in Table (28) and Fig. (17).

The relationship between the non-reducing sugars and the reducing sugars is much stronger during storage, the two components being dependent on each other. The increase in the reducing sugars during storage was the result of the decrease of the non-reducing sugars which means that the non-reducing sugars were transformed to reducing sugars. This relationship between the two components can very clearly be seen from the monosaccharide/disaccharide ratio Table (29). All the varieties had a ratio of less than 1 before storage, showing that they then had a non-reducing sugar content higher than the reducing sugar content. Throughout the storage period the ratio increased considerably. At the end of the storage period the reducing sugars exceeded the non-reducing sugars except the varieties Rose Carole and Rouge Fonce.

In Table (30) Fig (18) the changes of the total sugars, the non-reducing sugars and the reducing sugars are compared. They show the changes by taking the average value of each component for every period of storage. From the Table, it can be seen that the total and the non-reducing sugars decreased throughout the storage period. The decrease

T A B L E (28) EFFECT OF STORAGE ON THE REDUCING SUGARS OF DIFFERENT VARIETIES OF ONIONS (DRY BASIS)

Variety	Reducing Sugars (per cent)			
	After Harvest	1st Month	2nd Month	3rd Month
St. Michel	20.1	23.7	30.8	31.9
des Vertus	23.8	28.8	30.7	31.0
Rose Carole	10.9	10.8	13.8	18.7
Moulhouse (rondo)	17.4	22.6	25.4	28.7
Rouge Fonce	11.5	20.1	22.2	27.5
Rouge Niort	25.2	29.6	36.2	39.7
Moulhouse (flat)	19.9	22.3	27.8	33.7

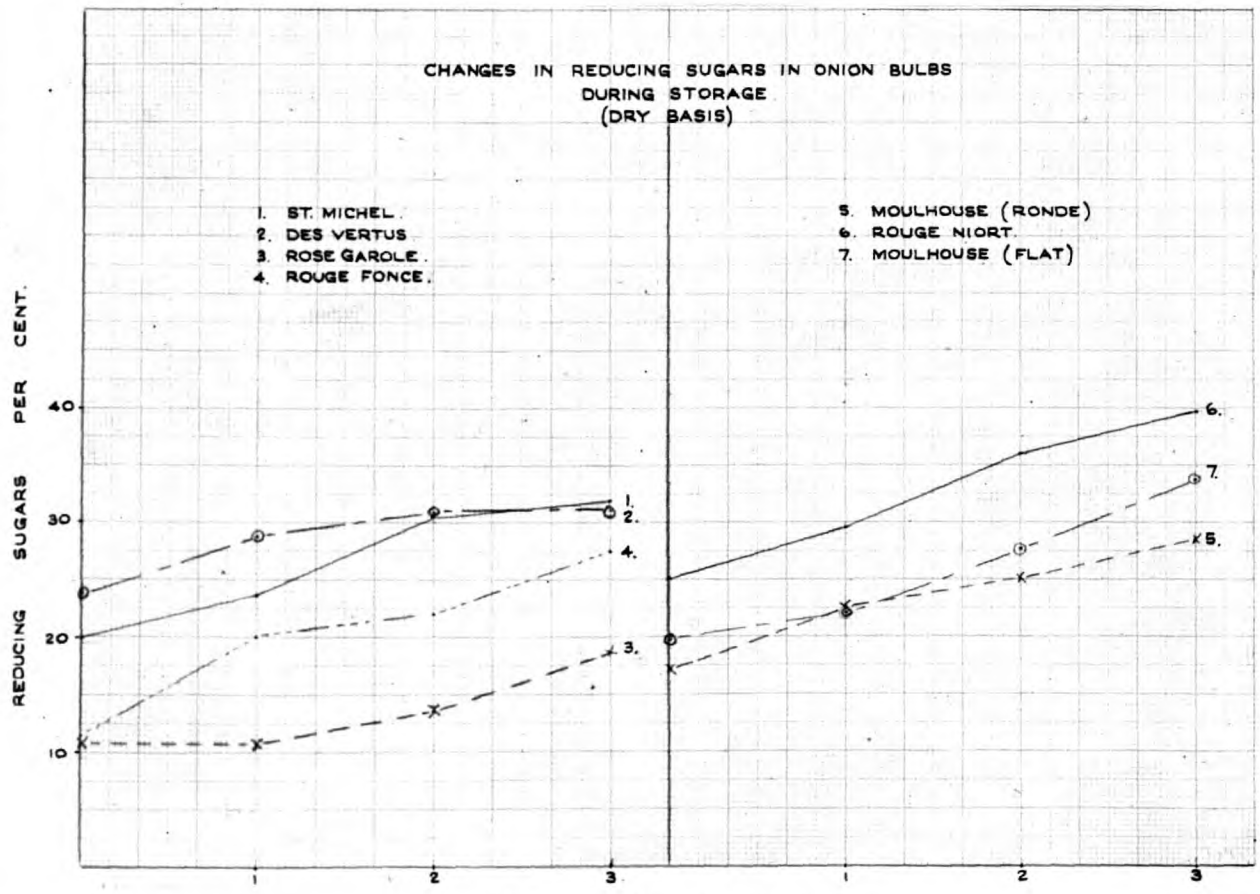

CHANGES IN REDUCING SUGARS IN ONION BULBS
DURING STORAGE
(DRY BASIS)
1. ST. MICHEL.
2. DES VERTUS
3. ROSE GAROLE.
4. ROUGE FONCE.
5. MOULHOUSE (RONDE)
6. ROUGE NIORT.
7. MOULHOUSE (FLAT)
REDUCING SUGARS PER CENT.
40
30
20
10
1
2
3
1
2
3
PERIOD OF STORAGE IN MONTHS.

FIG. 17.

T A B L E (29) EFFECT OF STORAGE ON THE MONOSACCHARIDES/ DISACCHARIDES RATIO OF DIFFERENT VARIETIES OF ONIONS

Variety	Monosaccharides/Disaccharides Ratio			
	After harvest	1st Month	2nd Month	3rd Month
St. Michel	0.48	0.70	1.19	1.54
des Vertus	0.62	1.09	1.37	1.63
Rose Carole	0.22	0.25	0.36	0.58
Moulhouse (ronde)	0.39	0.63	0.82	1.14
Rouge Fonce	0.22	0.50	0.61	0.93
Rouge Niort	0.80	1.15	1.97	3.44
Moulhouse (flat)	0.45	0.67	0.87	1.41

T A B L E (30) THE SUGAR COMPOSITION OF ONIONS DURING NORMAL STORAGE AS PER CENT OF DRY MATTER (CALCULATED FROM THE MEANS OF VARIETIES)

Time of determination	Total Sugar	Relative Value	Non Reducing Sugars	Relative Value	Reducing Sugars	Relative Value
	per cent		per cent		per cent	
After harvest	60.8	100	40.4	100	20.3	100
After 1st month	56.9	93.6	32.7	81.0	24.2	118.8
After 2nd month	55.4	91.0	27.3	67.9	28.1	137.9
After 3rd month	53.3	87.6	21.9	54.2	31.4	154.2

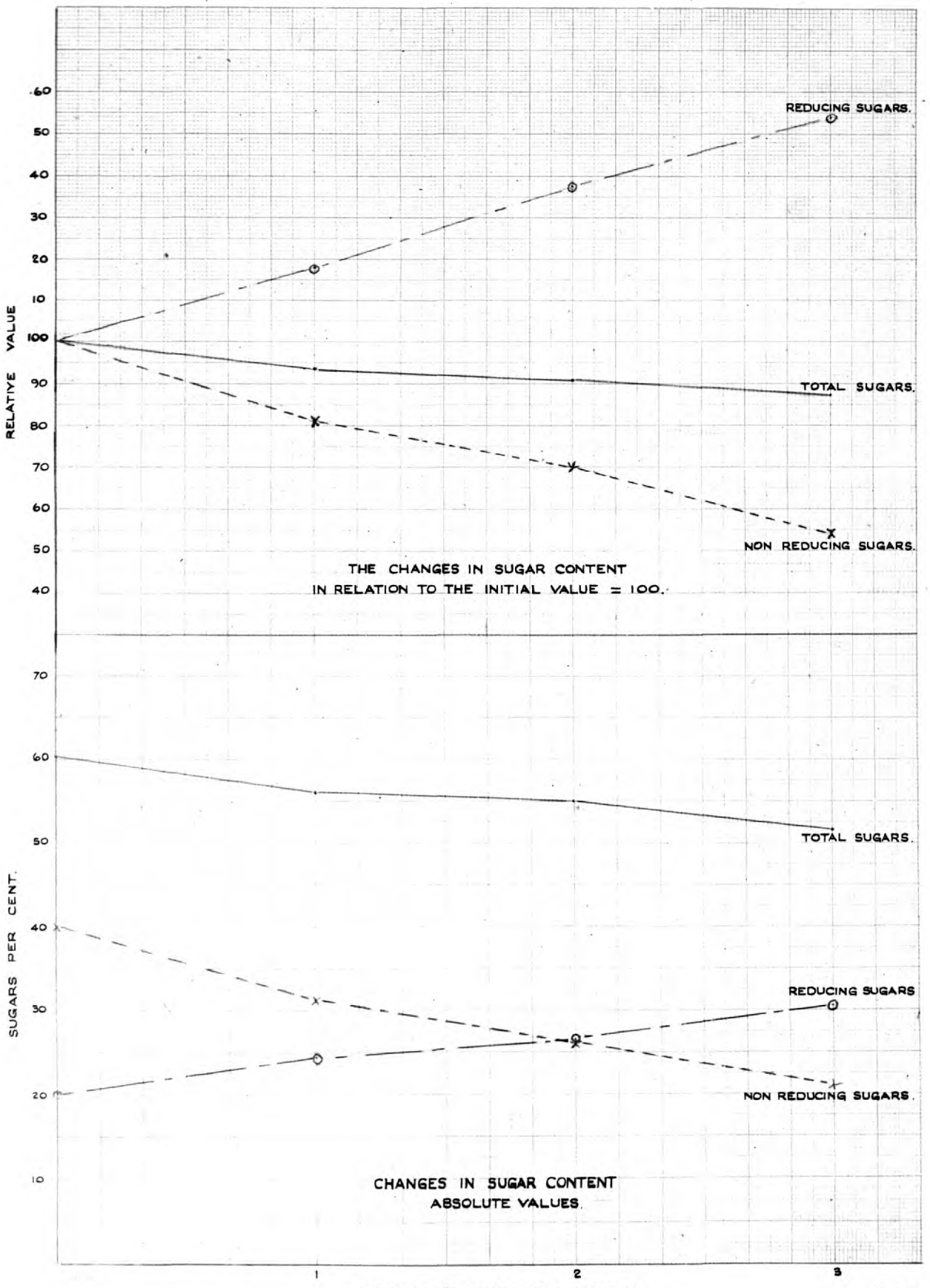

RELATIVE VALUE
60
50
40
30
20
10
100
90
80
70
60
50
40
REDUCING SUGARS.
TOTAL SUGARS.
NON REDUCING SUGARS.
THE CHANGES IN SUGAR CONTENT
IN RELATION TO THE INITIAL VALUE = 100.
SUGARS PER CENT.
70
60
50
40
30
20
10
TOTAL SUGARS.
REDUCING SUGARS
NON REDUCING SUGARS.
CHANGES IN SUGAR CONTENT
ABSOLUTE VALUES.
1
2
3
PERIOD OF STORAGE IN MONTHS.

FIG. 18.

of the latter was more than that of the former.

It is apparent from the Table that the bulb of the onion did not lose a great deal of its sugar content, although the non-reducing sugars decreased considerably.

During Autumn and Winter the onion bulb is dormant but still needs to draw slowly on its stored reserves. The non-reducing sugars are the form in which the carbo-hydrates are stored. For the utilization of this sugar, hydrolysis into its simpler component the reducing sugar appears necessary. The amount by weight of the reducing sugar resulting from a non-reducing sugar is nearly the same. So a considerable decrease in the total sugar (reducing and non-reducing) in a dormant plant would not be expected since the energy expenditure is at its minimum. This was the case in stored bulbs. This fact is confirmed by the results obtained for the total sugars, non-reducing sugar and reducing sugar. The steady but small decrease in the total sugars was due in fact to the utilization of sugars for the basal metabolism. The apparent increase in the reducing sugars was due to its formation by non-reducing sugar hydrolysis. Synthesis of sugars by photosynthesis can be ignored since the green foliage did not grow during the storage period and there was no exposure to sunlight. Emmett (96) reported that stored

onions lost from none to 8 per cent of its total sugars and that the largest percentage of reducing sugar was found in the coldest storage.

Scupin (98) found that onions stored for 8 - 9 months had decreased in the sugar content until half the storage period to increase again up to about the same content as before storage.

From a consideration of the data it seems that the sugar content of the onion had a great effect on the keeping quality of the onion during storage. This observation can be seen clearly from the behaviour of the variety Lescure. This particular variety had a very poor keeping quality during storage. From the results it had the lowest dry matter content and the lowest non-reducing sugar content in comparison with the other varieties. The reducing sugar exceeded the non-reducing sugar while the other varieties showed the opposite. All the varieties had a monosaccharide/disaccharide ratio less than 1 while this variety had a ratio more than.1. The variety Lescure did not keep at all even for the first month of storage, while the other varieties kept very well during the three months of storage.

GENERAL SUMMARY

The work presented in this thesis was designed to study the effect of dehydration on the onion at varying temperatures and air velocities and on its volatile sulphur, ascorbic acid and sugar content. The rate of drying was recorded under various conditions of dehydration. The effect of growth and storage on these components provided additional information.

The results obtained are considered in the separate sections of the thesis and may be summarized in the following.

(1) The various temperatures and air velocities had a great effect on the drying rate of the onion. The higher the temperature and air velocity the greater the drying rate. Temperatures higher than 60°C. were found to affect the onion and charring occurred at such high temperatures and all air velocities.

(2) Dehydration had a great effect on the volatile sulphur content of the onion. At all temperatures and air velocities the onion lost a considerable amount of its volatile sulphur. The highest percentage loss was at

75°, 70° and 50°C. and 400 and 650 f.p.m. Raising the air velocity to 900, 1150 and 1400 f.p.m. the losses were considerably less than at ~~650~~ 400 and 650 f.p.m. At 60°C and all air velocities the loss in volatile sulphur was the lowest and ranged from 11.3 to 28.8 per cent.

(3) Onions lost a considerable amount of their ascorbic acid during dehydration at all temperatures and air velocities. The highest percentage loss occurred at an air velocity of 1400 f.p.m. and all temperatures and ranged from 53.4 to 72.3 per cent. The lowest percentage loss occurred at 60°C. and all air velocities and ranged from 34.5 to 53.4 per cent. Dehydration at lower air velocities showed less effect on the ascorbic acid than dehydration at 1400 f.p.m.

(4) The sugar content of the onion was not affected by temperatures below 60°C. or by any variation in air velocity. Temperatures higher than 60°C affected the reducing sugars of the onion. The higher the temperature the greater the effect on the reducing sugars.

(5) Different varieties were dehydrated during 1951 and 1953 at a temperature of 60°C. and an air velocity of 1400 f.p.m. The percentage loss in volatile sulphur ranged from 7.0 to 47.3 per cent during 1951 and 9.2to 34.5 per cent

in 1952. The percentage loss in ascorbic acid ranged from 22.5 to 63.6 per cent in 1951 and 20.8 to 67.1 per cent in 1952. There was no significant difference between the sugar content of the fresh and dehydrated varieties in both seasons.

(6) The volatile sulphur content, which gives the onion its characteristic taste and odour, was estimated colourimetrically in different varieties of onions.

(7) The inherent characteristic of the different varieties examined had great influence on the volatile sulphur content. Some varieties were found to contain nearly twice as much volatile sulphur as others.

(8) French varieties when grown at Harlington increased in volatile sulphur oncomparison with the same varieties imported from France. On the other hand, the volatile sulphur content of the Egyptian variety decreased when compared with the sample imported from Egypt in 1951. This suggests that the different climatic conditions and different soils have a great influence on the volatile sulphur content.

(9) Changes in volatile sulphur during growth were determined in French and Egyptian varieties during 1952. A steady increase was observed during growth of the plant until it reached maturity.

(10) French varieties were stored during 1952 for 3 months and changesin volatile sulphur content observed. The general trend was an increase during the first two monthsof storage followed by a decrease during the third month.

(11) The ascorbic acid of different varieties of onions was estimated by the 2.6 dichlorophenolindophenol visual titration method and the indophenol xylene method for the coloured varieties.

(12) The varieties varied considerably in ascorbic acid content. The differencewas much more pronounced between the varieties grown under different conditions and locations than the varieties grown under the same conditions. The ascorbic acid content of French and Egyptian varieties grown at Harlington showed a large decrease compared with those from France and Egypt. This suggests that the growing conditions are one of the most important factors affecting the ascorbic acid content of onions.

(13) The changes in ascorbic acid of different varieties during growth were observed and discussed. The ascorbic acid decreased from the start until the plant reached maturity.

(14) Losses varying in magnitude from 21.3 to 50.0 per cent of the original values for fresh onions, occurred during 3 months of storage.

(15) The changesin the sugar content of different varieties of onions were studied during growth. The total sugars increased rapidly until they reached a maximum at a time which varied between the individual varieties. The general trend for the onion as a whole was that the maximum total sugars were reached during the third sampling. The total sugars were found to be the chief component of the dry matter. It composed 56.7 to 64.7 per cent of the dry matter.

(16) The non reducing sugars were found to be the major component of the total sugars. They formed 31.5 to 52.9 per cent. They changed in the same way like the total sugars. The varieties varied considerably in their non-reducing sugar content, some varieties were considerably high, others were exceptionally very low.

(17) The changes in the reducing sugar during growth were found to be in the opposite direction to that of the non-reducing sugars. It was also observed that the non-reducing sugars exceeded the reducing sugars for all the varieties except the variety Lescure.

(18) The relationship between the non-reducing sugars and the reducing sugars was expressed as the monosaccharides/disaccharides ratio. For all the varieties it was less than 1 with the exception of the variety Lescure which had

a ratio of more than 1. The changesin the ratio during growth showed that the reducing and non-reducing sugars behaved inversely.

(19) The total sugars decreased during storage for all varieties. At the end of the storage period the percentage loss ranged from 9.5 to 19.5 per cent. The non-reducing sugars decreased remarkably during storage. At the end of the storage period the percentage loss ranged from 33.6 to 64.7 per cent. On the other hand, the reducing sugars increased throughout the storage period which was clearly observed from the monosaccharides/disaccharides ratio which at the end of the storage period exceeded the value of 1 for the majority of the varieties.

(20) Although the non-reducing sugars decreased remarkably during storage, the bulbs did not show a great loss in the total sugars.

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