THE VITAMIN C VALUE OF COMMERCIALLY CANNED TOMATO JUICE

by

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INTRODUCTION

While severe scurvy is rarely seen in this country, thirty-five to sixty-six per cent of a group of children from poor homes were found by Dalldorf(9) to be suffering from subclinical scurvy. That such a condition exists in as advanced a country as the United States is appalling. While oranges, one of our best antiscorbutics, are being used in increasingly large quantities, they are still expensive. For the less expensive diet tomatoes, either fresh, canned, or prepared as juice, have been recommended to take the place of the more expensive orange juice. The fact is known that tomatoes retain considerable vitamin C potency in spite of the various methods of cookery. The extent to which the extracted juice retains its vitamin C potency is a factor to consider. Since tomato juice is purchased in such large quantities today by people of all economic levels, it becomes important to know more about the vitamin content of the various brands. In an attempt to determine accurately the vitamin C content of foods, various methods of determination have been evolved.

Methods of Vitamin C Determination

One reliable biological method was developed by Sherman, La Mer and Campbell[44] which takes into consideration the reaction of the guinea pig to a basal diet alone or that diet plus graded supplements of the food to be tested, as shown by the weight curve, survival period, and severity of the symptoms and autopsy findings. The severity of these autopsy findings, including hemorrhages, fragility of bones, and looseness of teeth, are determined and scored.

Höjer's[24] histological tooth method is short, requiring only 10 or 14 experimental days after the animals are eating the basal diet welland are growing. The test food is fed in addition to the basal diet, and at the termination of the experimental period all the animals are killed. One-half of the lower jaw is taken out and decalcified in 5 per cent tri-chloroacetic acid solution. Next it is embedded and sectioned after one week. The principal examination is made of the cross section of the incisor roots. Changes in the amount and character of the dentin, predentin, odontoblasts, and pulp are noted.

The curative method used by Parsons[41] is advantageous when the supplement to be studied is not available over an extended period of time. The first step in this method is to have the animals on an adequate diet; second, they are given a scorbutic diet upon which they develop scurvy symptoms within 10 to 20 days, at which time the product to be tested is fed. Upon the 15th day of the supplementary feeding the guinea pigs are chloroformed and autopsied to determine the extent of cure.

Formerly the biological were the only methods of determination, but since the discovery of the chemical nature of vitamin C, a chemical method has also been developed. Vitamin C has been found by King and Waugh[29] to be a hexuronic acid. This has been confirmed by others. The name proposed for this hexuronic acid was ascorbic acid, but the American Medical Association has also proposed the name of cevitamic acid. Ascorbic acid is a strong reducing agent and upon this property is based the present chemical method with its variations. The chemical method of Tillman as modified by Yavorsky, Almaden, and King[51] may be used, either with plant or animal tissues. A trichloroacetic acid extract of finely ground tissue is titrated with a solution of 2,6-dichlorophenolindophenol. The dye is reduced rapidly by the vitamin giving an end point, when the color disappears, in 5 to 10 seconds. When the titration is done quickly the interference of slow reducing substances such as glutathione is avoided.

Plant and animal tissues may also be tested by Tauber and Kleiner's method.[50] An acid ferricyanide solution is completely reduced by ascorbic acid in 3 minutes at 40° C. The amount of reduction by ascorbic acid is measured by treating an acid extract of the tissue with ferricyanide solution and ferric gum ghatti reagent. The Prussian blue formed is determined colorimetrically by comparing it with a standard solution of pure crystalline ascorbic acid treated in the same way.

A step farther has been taken in the development of a method for determining vitamin C deficiencies in humans. Göthlin[17] used in his work the method of measuring capillary resistance with the Rumpel and Leede apparatus. Pressure is applied by a constricting arm band for a considerable period (usually 15 minutes), which produces petechiae that occur in varying numbers when hemorrhagic diathesis is present caused by vitamin C deficiency. A series of such tests are necessary for reliable diagnosis.

Dalldorf[9] measured the amount of negative pressure needed to produce petechiae in normal individuals and those with varying degrees of vitamin C deficiency. This does not appear to give as reliable results as a series of the above tests.

An attempt has also been made to determine vitamin C deficiency in humans by use of the 2, 6- dichlorophenolindophenol indicator in urinalysis.[19] [20]

Factors Influencing the Vitamin C Content of Foods

The vitamin C in foods has been determined by both biological and chemical methods. In studying the vitamin C contents of foods the following factors have been found to affect the potency of the food: Growth, soil, fertilization, maturity, variety, method of ripening, season; application of heat, time, temperature, hydrogen-ion concentration, method of cookery, processing in canning, use of anti-oxidants; methods of preservation, cold storage, freezing, canning and drying. Various combinations of these factors have been studied by different investigators.

The vitamin C content of milk has been studied extensively. The pasteurization of milk is essential to insure a safer product, and while with pasteurization comes partial destruction of vitamin C, this need not be true if the process includes a short heating time, protection from atmospheric oxidation during heating, and a minimum of exposure to those metals which catalyze oxidation. King and Waugh[30] who observed the above precautions and used both the biological and chemical titration methods of determination, found that there was no significant destruction of vitamin C. When milk was heated at 143-5° for 30 minutes without the above precautions there resulted a significant loss of vitamin C. The vitamin C content of raw milk may depend upon the food of the cows as shown in the experiment of Hess, Unger and Supplee.[23] However, milk is not a rich source of vitamin C and ordinarily other sources of this vitamin are included in the diet.

Fellers[14] using both the biological and titration method with ascorbic acid as a standard, studied 43 samples of fresh or manufactured fruit products, and 18 samples of vegetables. He found that in short cooking, peas, asparagus, lima beans, and spinach lost 40 to 80 per cent of their vitamin C. The loss in canning varied from 60 to 90 per cent. Cooked, frozen vegetables were slightly lower in vitamin C than fresh cooked, but were considerably higher than the canned vegetable which had been heated for the table. Also, canned, sieved vegetables, such as are now extensively used as baby foods, had the same or lower vitamin C values than the unstrained canned vegetables.

The effect on asparagus of fertilization was further investigated by Fellers, Young, Isham and Clague[16], who concluded that variation in the amount of potash and nitrogen used in the fertilization did not appreciably affect the vitamin C content of the vegetable.

Newton[40] also using the biological method, found one ounce of raw turnip greens to contain 14 units of vitamin C; greens boiled two hours contained 6 units to the ounce; greens blanched in boiling water and canned contained 7 units to the ounce; while the steam-blanched canned product showed practically no loss. Raw collards were found to be a richer source of vitamin C than turnip greens, one ounce containing 57 units; after boiling for two hours one ounce of collards contained only 14 units. This represented an even greater loss in cooking than that found with turnip greens; however, the collards were still a much richer source of vitamin C than turnip greens.

Several groups of workers have investigated the vitamin C content of spinach. Kifer and Munsell[28] studied three different varieties to determine whether there was a correlation between leaf type and leaf color. The results indicated that Princess Juliana, a savoy leaved type, dark blue green in color, contained less vitamin C than the Virginia Savoy, a heavily savoyed leaf type, dark green inclined toward a blue green in color, or Viroflay, a smooth or flat leaved type, somewhat yellow green in color. The biological method was used. Halliday and Noble[18] using the chemical method with spinach studied the effects of soil, variety of plant and the part of it used, and conditions of storage on the vitamin C content. Ontario clay soil gave a spinach about three times as rich in ascorbic acid as muck soil. Princess Juliana variety was lower in vitamin C content than either the Nakimo or Broad Flanders. There was 13 to 20 times as much vitamin C in the leaves as in the stems. Spinach stored at room temperature lost one-half its vitamin C potency in three days, while spinach stored between 1 and 3° C. retained nearly all its vitamin C for the three day period.

Eddy, Kohman and Halliday[13], found that after three years' storage the same amount of canned spinach protected guinea pigs from scurvy as when it was freshly canned. Eddy, Kohman and Carlsson[12] concluded that the process of canning spinach as carried out commercially preserves the antiscorbutic factor to the extent of making such food an important source of vitamin C.

The vitamin C potency of home-canned carrots was studied by Spohn and Hunter[49], who found that practically all the vitamin C present in raw carrots was destroyed when the carrots were canned by the cold pack method with a small amount of vinegar and heated in a water bath for 90 minutes, or when they were canned with or without vinegar in a steam-pressure cooker for 40 minutes at 10 pounds pressure.

Clow, Marlott, Peterson and Martin[6] found the vitamin C content of fresh raw sauerkraut to be approximately one-half that of raw cabbage. Six brands of commercially canned sauerkraut were studied by Clow, Parsons and Stevenson[7], who found considerable variation in the vitamin C losses in the different brands. The poorest brand was about one-half as rich as the fresh raw sauerkraut, or one-fourth as rich as fresh cabbage. Further research was done by Parsons and Horn[42] after an attempt had been made to control the methods of manufacture of four of these brands. However, uniform results were not obtained, several brands having greater losses than the year before. The protective biological method was used.

Scurvy is said to increase and decrease as the potato crop increases or decreases. This is probably due to the fact that such large quantities of potatoes are eaten rather than that potatoes are an exceptionally rich source of vitamin C. However, McKittrick and

Thussen[37] found that the vitamin C content of fall potatoes apparently was not decreased by cookery. They further found that there was some destruction of the vitamin during six months' storage; therefore, winter and spring potatoes were a poorer source. There was better retention of vitamin C during storage of potatoes grown on dry land than on irrigated land.

Not only vegetables but also fruits have been investigated for their vitamin C values. The Höjer tooth method was used by Daniels and Munsell[11] to determine the vitamin C in Concord grapes. This variety of grapes was found devoid of the vitamin, possibly because the skins were discarded as inedible. In previous work Malaga (seeded) and Sultanina (whole seedless) grapes were found to contain small amounts of this vitamin.

The effect of drying and sulphuring on the vitamin C content of prunes and apricots has been determined by Morgan, Field and Nichols.[38] Frozen fresh prunes retained their vitamin C but frozen fresh apricots lost this property. When the air in the cases was replaced by nitrogen before the fruit was frozen the vitamin C was retained. Sulphured, dehydrated and sun-dried prunes retained the vitamin C of fresh fruit satisfactorily only when lye dipped before the sulphur dioxide treatment. Dehydrated and sun-dried apricots retained the antiscorbutic property only when a definite proportion of sulphur was used. Both the dehydrated prunes and apricots retain the vitamin better than the sun-dried as determined biologically.

Fellers[14] classified the fruits studied as follows: In general, fresh and canned citrus fruits and tomatoes, as well as their juices are excellent antiscorbutics; blueberries, strawberries, cranberries, certain apple varieties, pineapple and asparagus are good secondary sources of vitamin C. Grapes, grape juice, peaches, cherries, prunes, pears, and certain other varieties of apples are poor sources of vitamin C. Smith and Fellers[47] in a more extensive work found 21 varieties of apples to vary widely in vitamin C content, the best being five times as potent as the poorest. Of the varieties of apples studied by Manville, McMinis and Chuinard[36] the Yellow Newtown proved to be the most potent source of vitamin C, while the Winesap, which Fellers had found especially good, was only half as potent as the Yellow Newtown. Potter and Overholser[43] found Winesap apples from trees receiving applications of a complete fertilizer to be a better source of vitamin C than those from unfertilized trees. Crane and Zilva[8] likewise found certain English varieties of apples to vary in their vitamin C content.

Factors influencing the canning of apples were tested by Kohman, Eddy and Carlsson.[31] The biological method was used and their results indicated that there was no destruction in canned apples (Albermale Pippin) after eight months' storage; cold storage of apples from October to March resulted in marked deterioration of vitamin C. Applesauce, baked apples, or apples canned without special treatment lost practically all their vitamin C. This vitamin is preserved in canning apples by covering the apples with a salt solution and leaving it long enough to allow the respiratory system to use up all the dissolved oxygen.

Fresh yellow cantaloupes contain about 10 units of vitamin C per ounce. Frozen peaches contain less than 0.5 units per ounce of vitamin C, as found by Newton[40] in biological studies.

Orange juice when frozen with precautions against oxidation and stored for 20 months was found by Buskirk, Bacon, Tourtellotte and Fine[4] not to deviate essentially in vitamin C content from fresh juice. Also, Morgan, Langston and Field[39] found that two-thirds of the vitamin C content of fresh orange juice was present in a sweetened commercial orange juice containing sodium benzoate. The loss in this orangeade was probably due to dilution by sugar. Pasteurized orange juice bottled with carbonated water retained its full vitamin C content. Orange juice when subjected to oxygen for a short period was found by Hess and Unger[22] to have lost some of its vitamin C potency.

Pears grown in both Oregon and Washington have been studied by Manville and Chuinard[34][35] as to the vitamin C potency after different conditions of storage. Under optimal storage conditions the following potencies were given: Bosc, 2.5 units per ounce; D'Anjou, 4 units per ounce; and Winter Nelis, 3 units per ounce. They report that prolonged storage, for two months after the fruit is ordinarily off the market, caused a loss of nearly 50 per cent in vitamin C potency. No difference in the vitamin C values of the fruits grown in different regions was found. However, the method of determining these units might be questioned, because the unit of vitamin C which Manville reports, differs from the defined unit of the method employed.

Ivanov[26] and his coworkers have studied numerous foods of Russia for their vitamin C content, and for factors influencing this content. They found that some of their native berries are exceptional sources of this vitamin. Also, some of their vegetables are good sources, depending somewhat upon the locality in which they are grown.

Tomatoes, although a fruit, are considered a vegetable and are used as both. The tomato and its juice have been studied by a number of workers. As cited above, Fellers, Clague and Isham[15] found that the vitamin C content of different brands of commercial juice and juice prepared in the laboratory varied, some being about four times as potent as others. Also, they found that there was a difference in vitamin C potency, depending upon the variety of tomatoes used. Homogenization of the juice made no significant difference in the vitamin content.

The same results were obtained by Barnby and Eddy[2], who found homogenized tomato juice retained practically all its vitamin C content. The type of container, glass or tin, made no difference, but the consistency of the juice did. The thicker the juice, the more air was trapped as tiny bubbles in the fibre, and correspondingly, the more vitamin C was oxidized. This was observed by Kohman, Eddy and Zall.[33] They further observed that any preliminary process in the canning of tomato juice which introduced air, destroyed vitamin C in proportion to the time of exposure and the temperature to which the product was subsequently heated.

The hydrogen ion concentration was still another factor given consideration. Sherman, La Mer and Campbell[45] found less destruction of vitamin C in tomato juice when it was boiled at its natural acidity than when it was partially neutralized. There was even greater destruction of vitamin C when the juice was made alkaline. Sherman and associates[44] found 3 c.c. of juice of strained, canned tomatoes to be a protective dose for guinea pigs. More than half this potency remained after one year's storage. Hess and Unger[21] tested the juice of canned tomatoes stored about one year and found 5 c.c. to be the protective amount.

The juice of home canned tomatoes was studied by Spohn[48] who found it to have a lower potency of vitamin C than the juice of fresh tomatoes. The tomatoes were cold-packed and processed for 20 minutes. A 4 c.c. dose of the home-canned juice was not protective to guinea pigs while 3.5 c.c. of the raw juice was protective.

The above discussion has been chiefly of canned tomatoes and juices, but tomatoes are different from some other rich sources of vitamin C in that they are eaten raw; and so may be had in their most potent form. Today ripening by ethylene and other artificial methods are commonly used. House, Nelson and Haber[25]; Clow and

Marlott[5]; Kohman, Eddy and Zall[33]; and Jones and Nelson[27] all agree that vine ripened tomatoes are superior in vitamin C content to ethylene or air ripened tomatoes, but the ethylene ripened were found to be as good as the air ripened. Clow and coworkers obtained results which seemed to indicate that canned green tomatoes were more potent than raw green tomatoes; however, Kohman and associates pointed out that the previous treatment of the tomatoes might explain these findings. The raw green tomatoes were ground, which might result in rapid oxidation of the vitamin C. Jones and Nelson found full grown green tomatoes better sources of vitamin C than the immature fruit, which would indicate that the vitamin develops with maturity. Clow and Marlott obtained a high preservation of the vitamin C content of the tomato in canning with the cold-pack than with the open-kettle method.

In a preliminary test in this laboratory 3 c.c. of canned tomatoes was found to be a protective dose, while 3 c.c. of commercially canned tomato juice in this study was not protective.

Purpose of This Study

Three brands of commercially canned tomato juices were selected for comparison of their vitamin C potency.

One of these brands was canned by the Department of Horticulture at Oregon State College. The two other brands were purchased at a local grocery store. Tomato juice is highly advertised for its antiscorbutic qualities but not all juices have the same potency. Fellers and associates[15] working with five brands of commercially canned and eleven different laboratory prepared tomato juices found the protective doses to range from 2 to 7 c.c. a day. Therefore, it seemed of value in a different locality to study the vitamin C of brands of juices used commonly in this section of the country. Conditions comparable to those found in the home were used in handling and storing the juices during the experimental period.

EXPERIMENTAL

The method used to test the vitamin C potency was that of Sherman, La Mer and Campbell[44], as modified by Batchelder, Miller, Sevals and Starling.[3] This consisted of feeding guinea pigs for 56 days a basal diet free from vitamin C, plus measured amounts of the substance to be tested. At the end of the experimental period the animals were killed and autopsies made to determine the degree of protection against scurvy.

Animals

Healthy young guinea pigs 6 to 8 weeks old and weighing 200 to 300 grams, averaging 263 grams, were obtained from the Department of Veterinary Medicine at Oregon State College. They were placed in individual metal cages with raised screen bottoms, and were given the basal diet plus cabbage *ad libitum* until they were accustomed to the food and were growing normally. This period varied from 7 to 13 days, at the end of which time they weighed from 236 to 390 grams, the average weight being 300 grams. Then the cabbage feeding was stopped and the experimental period begun. Fresh water and food were provided daily. The cages were changed every two or three weeks or oftener if necessary. All animals were weighed three times a week. The amount of supplement was calculated in proportion to 300 grams of body weight each time the animals were weighed. All animals were fed the tomato juice by hand from a pipette graduated to 0.1 c.c., daily except Sunday. On Saturday and Monday one and one-half times the amount of supplement was given.

Basal Diet

The basal diet consisted of the following:

Baked skimmilk powder	30 %
Butterfat	9 %
Cod liver oil	1 %
Salt	1 %
Dried yeast	5 %
Rolled oats	36 %
Bran	18 %
	100 %

This food was mixed fresh twice a week and stored in an icebox.

Preparation of Constituents of the Basal Diet

Skimmilk powder was baked for four hours at 110° C. in electric ovens, until light buff in color. It was stirred frequently to prevent burning and scorching. The four hour baking period was used instead of the two hours used by Sherman, La Mer and Campbell[44], to be doubly sure that all the vitamin C was destroyed.

Butterfat was prepared by melting fresh creamery butter at a temperature below 40° C., decanting and filtering through absorbent cotton in order to remove the curd, salts and water present.

Supplements

Commercially canned tomato juices. The tomato juices used were two well known brands and two different lots of the juice canned by the Department of Horticulture of Oregon State College. Brands A and B were purchased from a local grocer by the case in No. 1 tall cans. Brand C (the O.S.C. juice) consisted of a mixed case of two lots in No. 2 cans. The juice from the two lots was used alternately. When received, the cases were placed on a shelf in the laboratory at room temperature.

In their tests Sherman, La Mer and Campbell[44] opened their cans of tomatoes at five day intervals. Fellers, Clague and Isham[15] opened their cans of tomato juice daily. In this investigation the cans were opened on Mondays and Thursdays. Before the cans were opened they were well shaken. Two small holes were punched in the top, the juice being left in the can, because the less the juice was disturbed after opening the less oxygen would be introduced to cause oxidation of the vitamin C. Each day enough juice for the day's feeding was poured from the can into a small container. Then the can of juice was placed in the coldest part of an icebox.

Separate pipettes were used for each of the three brands of juice. These pipettes were washed carefully daily.

Crystalline vitamin C (cevitamic acid) obtained from Merck and Company was made up in the proportion of 0.2 gram per 100 c.c. of solution, about every two weeks, and kept in the coldest part of an icebox. The positive control animal was fed 1.5 c.c. of the solution per 300 grams body weight, daily by pipette. This corresponded to 0.003 gram of ascorbic acid. Dann and Cowgill[10] found 1 c.c. of lemon juice per 100 grams guinea pig to be a protective dose. The International Unit of vitamin C is now 0.05 mg. l-ascorbic acid[1] which is the equivalent of 0.1 c.c. lemon juice. Therefore, Dann and Cowgill in feeding 1 c.c. of lemon juice were giving the equivalent of 0.0015 gram of ascorbic acid per 300 gram guinea pig.

Plan of Experimental Series

The animals were divided into 8 groups with 1 to 5 guinea pigs in a series. They were grouped according to average weight and sex as far as possible. Although the number of animals used in each series was small, the results obtained allow certain conclusions to be drawn.

Since a preliminary experiment had been carried out which included two negative and two positive control animals, there were only two negative control animals and one positive control used in this experiment.

Series I   Basal diet alone

Series II   Basal diet plus ascorbic acid solutionn.

The remainder of the experimental series was concerned with the feeding of two levels of the three brands of canned tomato juice. In determining the amounts of juice to be used the results of other workers were examined. Fellers, Clague and Isham[15] in their work found that from 2 to 7 c.c. of different brands of tomato juices contained protective amounts of vitamin C. However, Kohman, Eddy and Gurin[32] using 5 c.c. and 3 c.c. levels found at autopsy that only one animal of the six receiving 5 c.c. was free of scurvy symptoms. In the present study 3 c.c. and 5 c.c. amounts were selected with the desire of approaching the protective level.

Series III   Basal diet plus 3 c.c. of Brand A tomato juice per 300 gram guinea pig.

Series IV   Basal diet plus 5 c.c. of Brand A tomato juice per 300 gram guinea pig.

Series V	Basal diet plus 3 c.c. of Brand B tomato juice per 300 gram guinea pig.
Series VI	Basal diet plus 5 c.c. of Brand B tomato juice per 300 gram guinea pig.
Series VII	Basal diet plus 3 c.c. of Brand C (O.S.C.) tomato juice per 300 gram guinea pig.
Series VIII	Basal diet plus 5 c.c. of Brand C (O.S.C.) tomato juice per 300 gram guinea pig.

Criteria for Determination of the Results

Sherman, La Mer and Campbell state that dependence cannot be placed upon any one group of symptoms in the experimental animals; therefore it is better to consider the following: The weight curve, survival period, and severity of symptoms, and autopsy findings.

At autopsy on the 56th day, or upon death of the negative controls, observation was made on each animal for hemorrhages and fragility of bones and looseness of the teeth as indications of the severity of scurvy. The animals were scored according to the Sherman scurvy score.[(46)] Plus signs were used to indicate the varying degree of the above symptoms of scurvy. The sum of the plus signs indicate the severity of scurvy.

RESULTS AND DISCUSSION

The results obtained were as follows: In feeding 1.5 c.c. of the crystalline ascorbic acid solution there was complete protection from scurvy as judged by observation, gain in weight, and by examination at autopsy. This positive control animal ate the basal diet well and was fully normal in every way so far as could be seen (Tables 1 and 2, Chart 1).

On feeding the basal diet alone there was good initial growth followed by great loss in weight. Death from scurvy resulted within 24 to 28 days. These animals remained sleek looking with good general appearance up until the last week of life, although there were symptoms of sore joints earlier. Blood was found on the bottom of the cage of animal No. 136, indicating hemorrhage in the intestine. Autopsy revealed allthe signs of severe scurvy; namely, hemorrhages, fragility of bones, and looseness of teeth.

As shown in Tables 3 and 4, when 3 c.c. of Brand A tomato juice were fed, the animals continued to grow, reaching their maximum weights on the 56th, 45th, and 53d days, respectively. However, they did not reach as great a weight nor had they the sleek, good, general appearance of those receiving 5 c.c. of juice. No soreness of joints was observed. Upon autopsy at 56 days the ribs, joints and muscles showed some hemorrhage, the jaws moderate fragility; the teeth were not loose, and the jaws and ribs fairly well protected. Guinea pig No. 122 had a sore right eye from the 30th to the 38th day, probably due to a cold. Boric acid solution was used in treatment.

When 5 c.c. of Brand A tomato juice were fed, the animals were completely protected from scurvy as judged by examination both during life and at autopsy, except that guinea pig No. 123 showed mild hemorrhage in the joints.

In feeding 3 c.c. of Brand B tomato juice, the animals were found to be not as well protected as those receiving 3 c.c. of Brand A. Growth of the animals was neither uniform nor continuous as can be seen by the growth curves. Their maximum weights were attained on the 56th, 33d, 32nd, and 45th days with subsequent losses of 0, 23, 53, and 106 grams, respectively. Guinea pigs Nos. 113 and 114 were better protected than Nos. 125 and 126. The teeth of none of the animals were loose; the fragility of the jaws, ribs, and joints varied from mild to severe. Hemorrhages were relatively mild, while the bones were fragile (see Tables 5 and 6). Three animals, Nos. 114, 125 and 126, had hard white spots on the liver and lung, and a hard growth in the intestine, probably due to coccidiosis.

The animals receiving 5 c.c. of Brand B tomato juice were completely protected from scurvy as measured by this method. However, guinea pig No. 128 had the same kind of hard white growths in the liver and intestines as mentioned above; also this animal had a cold in the left eye intermittently from the 7th to the 40th day.

On feeding 3 c.c. of Brand C (Oregon State College tomato juice) the animals continued to grow, four reaching their maximum weight on the 56th day, and one on the 53d day. There were no outward symptoms of scurvy during life with these guinea pigs except in No. 117, which showed signs of sore joints, especially in the hind legs. Judging from the absence of scurvy symptoms and from the good growth of these animals it would seem that Brand C juice was somewhat better than the other two. Upon autopsy there were mild or moderate degrees of fragility in the jaws, ribs, and joints; and mild hemorrhage of ribs, intestines, joints, and muscles. In no case were the teeth loose. Again the growths on the liver were found in two cases, Nos. 129 and 130, but in mild form. The average scurvy score for these guinea pigs fed 3 c.c. of Brand C (O.S.C.) tomato juice was 3.8, while the average scores on Brands A and B were 5.2 and 6.5 respectively. This confirms the observation above that Brand C was somewhat better than the other two brands. (Tables 7 and 8, Charts 6 and 7.)

The animals receiving 5 c.c. of Brand C (O.S.C.) tomato juice were completely protected from scurvy as determined by observation during life and examination at autopsy, except that guinea pig No. 120 had possible slight hemorrhage of the ribs and animal No. 131 had a trace of hemorrhage of the joints. Guinea pigs Nos. 119 and 132 had colds in the eyes for a few days' duration.

SUMMARY AND CONCLUSIONS

Three brands of commercially canned tomato juice, including the Oregon State College brand, were studied for their vitamin C values.

Complete protection from scurvy in young growing guinea pigs resulted from feeding 5 c.c. of all three brands, as judged by this method. In no case was the 3 c.c. level a protective dose. Therefore, the amount of these juices containing 1 unit of vitamin C is between 3 and 5 c.c.

The averages of the scurvy scores on the 3 c.c. levels of the various juices were: Brand C (Oregon State College), 3.8; Brand A, 5.2; and Brand B, 6.5.

A study of these scores, together with observations of growth rate and symptoms during life indicate that the Oregon State College product is somewhat superior in vitamin C content to the other two brands. This conclusion, however, pertains only to the particular lots of juices studied.

Table 1. The Effect of a Basal Diet With and Without Ascorbic Acid on the Growth and External Symptoms of Scurvy in Guinea Pigs.

			Body Weight				
Series No.	Animal No.	Supplement of ascorbic acid	Initial grams	Maximum grams	Final grams	Duration of experiment	Symptoms
		c.c.					
I	134♀	1.5	330	540	540	56	none
II	135♀	0	390	407	233	24	v.severe
	136♀	0	255	301	159	28	v.severe

Table 2. Autopsy Findings in Guinea Pigs Fed a Basal Diet With and Without Ascorbic Acid.

			Bony System				Hemorrhages				
Series No.	Animal No.	Supplement of ascorbic acid	Jaw	Teeth	Ribs	Joints	Ribs	Intestines	Joints	Muscles	Total score
		c.c									
I	134♀	1.5	-	-	-	-	-	-	-	-	0
II	135♀	0	+++	+++	++	+++	+++	+	+++	++	20
	136♀	0	+++	+++	+++	+++	+++	++	+++	+++	23

Table 3. The Growth and External Symptoms of Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand A Tomato Juice.

			Body Weight				
Series No.	Animal No.	Supplement of tomato juice c.c.	Initial grams	Maximum grams	Final grams	Duration of experiment	Symptoms
III	109♂	3	239	296	296	56	mod.
	110♀	3	367	431	418	56	mod.
	121♂	3	254	462	461	56	mod.
	122♀	3	331	556	546	56	mod.
IV	111♀	5	276	453	447	56	none
	112♂	5	325	571	550	56	none
	123♂	5	290	621	621	56	none

Table 4. Autopsy Findings in Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand A Tomato Juice.

			Bony System				Hemorrhages				
Series No.	Animal No.	Supplement of tomato juice	Jaw	Teeth	Ribs	Joints	Ribs	Intestines	Joints	Muscles	Total score
		c.c.									
III	109♂	3	-	-	-	+	++	tr	+	++	6
	110♀	3	-	-	-	+	+	-	+	-	3
	121♂	3	+	-	+	+	+	-	-	+	5
	122♀	3	+	-	+	+	+	-	+	++	7
IV	111♀	5	-	-	-	-	-	-	-	-	0
	112♂	5	-	-	-	-	-	-	-	-	0
	123♂	5	-	-	-	-	-	-	+	-	1

Table 5. The Growth and External Symptoms of Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand B Tomato Juice.

			Body Weight				
Series No.	Animal No.	Supplement of tomato juice	Initial grams	Maximum grams	Final grams	Duration of experiment	Symptoms
		c.c.					
V	113♀	3	266	399	399	56	mild
	114♀	3	356	411	387	56	mild
	125♀	3	261	291	238	56	severe
	126♀	3	328	332	211	56	severe
VI	115♂	5	286	592	592	56	none
	116♀	5	300	483	479	56	none
	127♀	5	279	431	420	56	none
	128♂	5	323	546	546	56	none

Table 6. Autopsy Findings in Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand B Tomato Juice.

			Bony System				Hemorrhages				
Series No.	Animal No.	Supplement of tomato juice	Jaw	Teeth	Ribs	Joints	Ribs	Intestines	Joints	Muscles	Total score
		c.c.									
V	113♀	3	+	-	-	-	+	-	-	-	2
	114♀	3	-	-	+	-	-	-	-	-	1
	125♀	3	++	-	+++	+++	-	-	++	+	11
	126♀	3	+++	-	++	+	+	+	++	++	12
VI	115♂	5	-	-	-	-	-	-	-	-	0
	116♀	5	-	-	-	-	-	-	-	-	0
	127♀	5	-	-	-	-	-	-	-	-	0
	128♂	5	-	-	-	-	-	tr	-	-	tr

Table 7. The Growth and External Symptoms of Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand C (C.S.C.) Tomato Juice.

			Body Weight				
Series No.	Animal No.	Supplement of tomato juice c.c.	Initial grams	Maximum grams	Final grams	Duration of experiment	Symptoms
VII	117♀	3	267	340	340	56	severe
	118♀	3	350	502	502	56	v. mild
	129♀	3	290	473	464	56	mild
	130♀	3	300	471	471	56	v. mild
	133♀	3	236	447	447	56	v. mild
VIII	119♀	5	294	461	456	56	none
	120♀	5	300	490	475	56	none
	131♂	5	296	522	522	56	none
	132♂	5	297	605	605	56	none

Table 8. Autopsy Findings in Guinea Pigs Receiving 3 c.c. and 5 c.c. of Brand C (O.S.C.) Tomato Juice.

			Bony System				Hemorrhages				
Series No.	Animal No.	Supplement of tomato juice c.c.	Jaw	Teeth	Ribs	Joints	Ribs	Intestines	Joints	Muscles	Total score
VII	117♀	3	++	-	++	++	+	+	-	+	9
	118♀	3	-	-	-	+	-	-	-	-	1
	129♀	3	+	-	+	+	-	tr	+	-	4
	130♀	3	-	-	-	-	-	-	+	+	2
	133♀	3	+	-	-	-	+	-	tr	+	3
VIII	119♀	5	-	-	-	-	-	-	-	-	0
	120♀	5	-	-	-	-	?	-	-	-	?
	131♂	5	-	-	-	-	-	-	tr	-	tr
	132♂	5	-	-	-	-	-	-	-	-	0

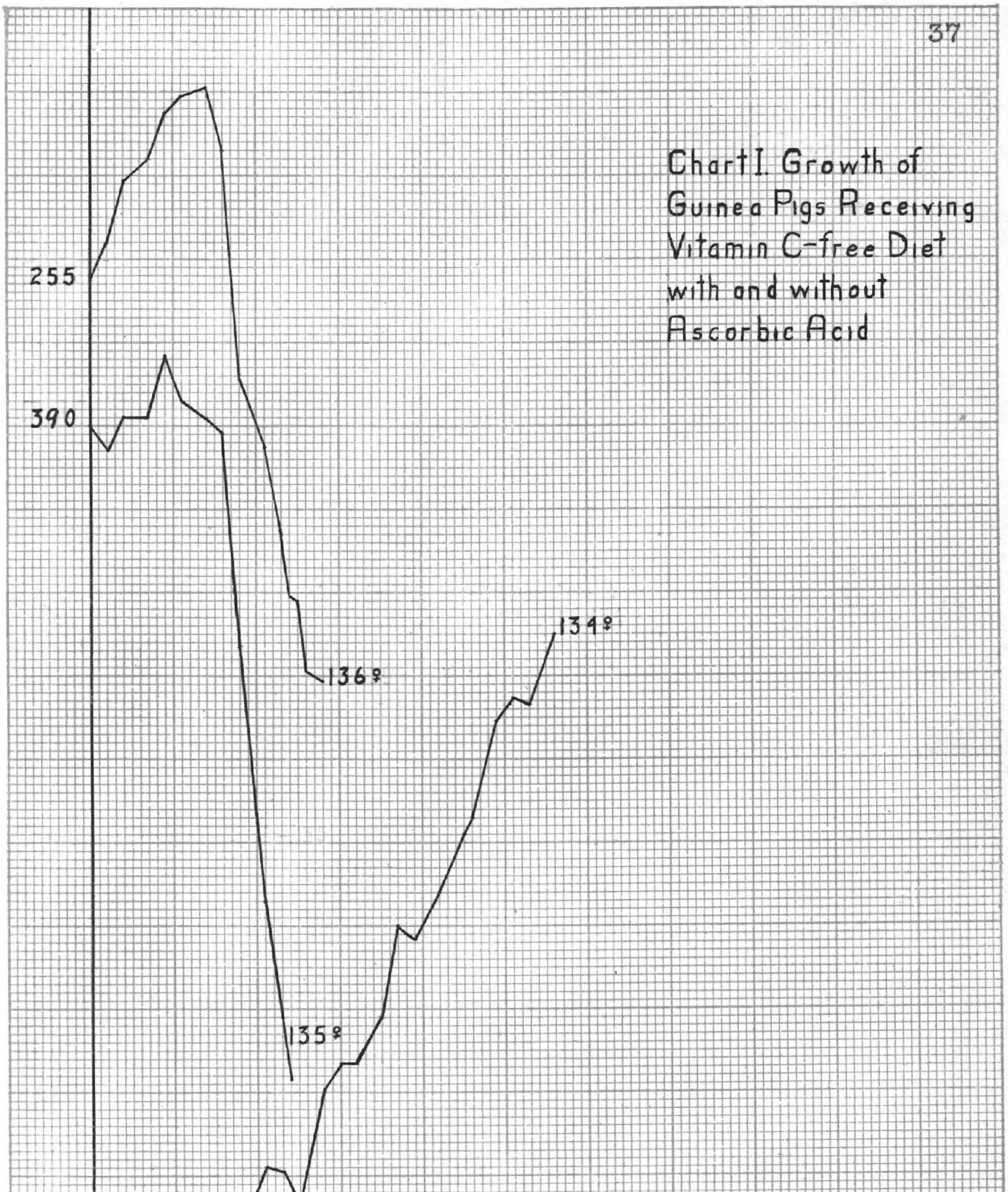


Chart I. Growth of Guinea Pigs Receiving Vitamin C-free Diet with and without Ascorbic Acid
255
390
330
136♀
135♀
134♀
20 grams
10 days

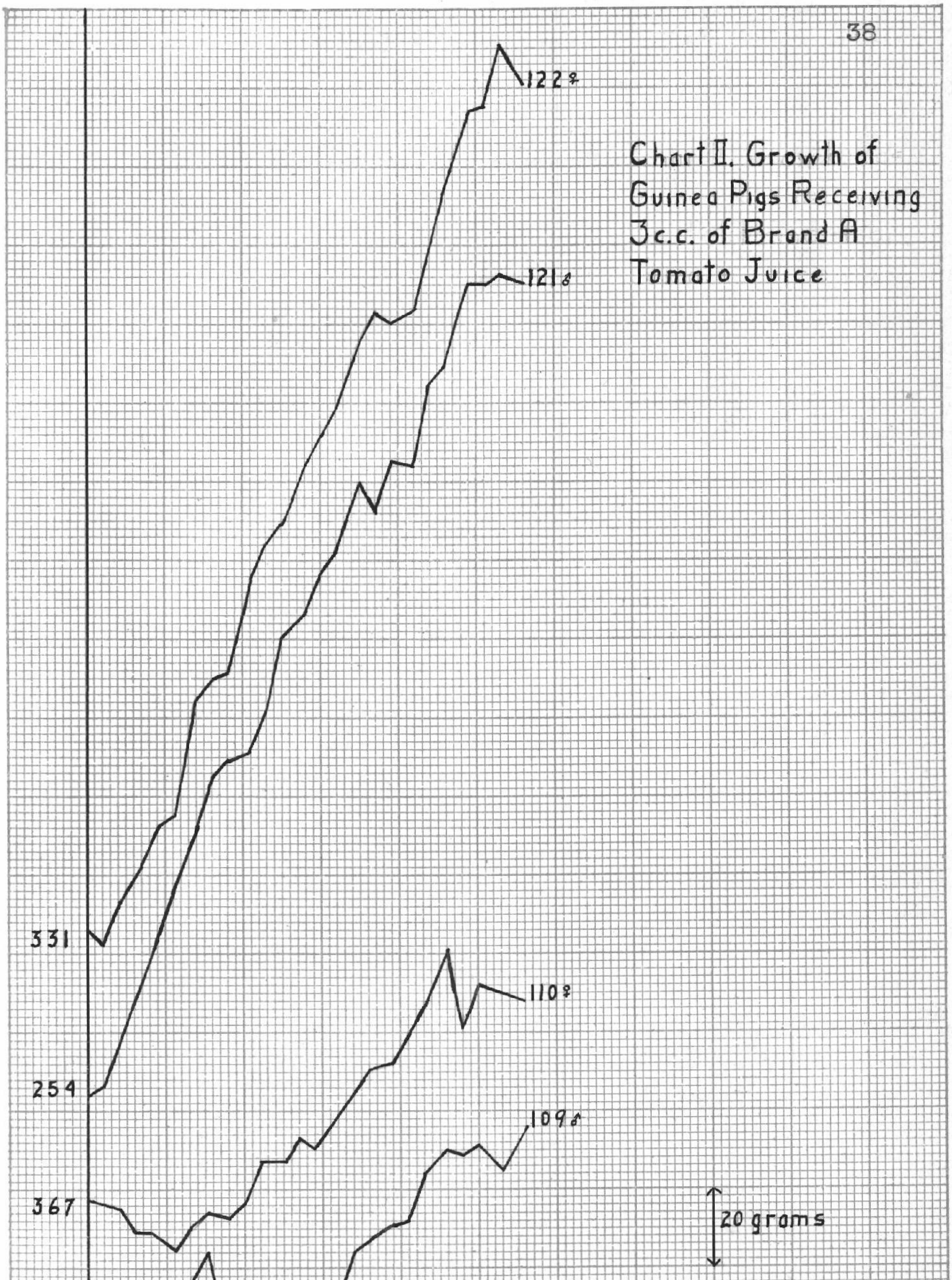


Chart II. Growth of Guinea Pigs Receiving 3c.c. of Brand A Tomato Juice
122♀
121♂
110♀
109♂
331
254
367
239
20 grams
10 days

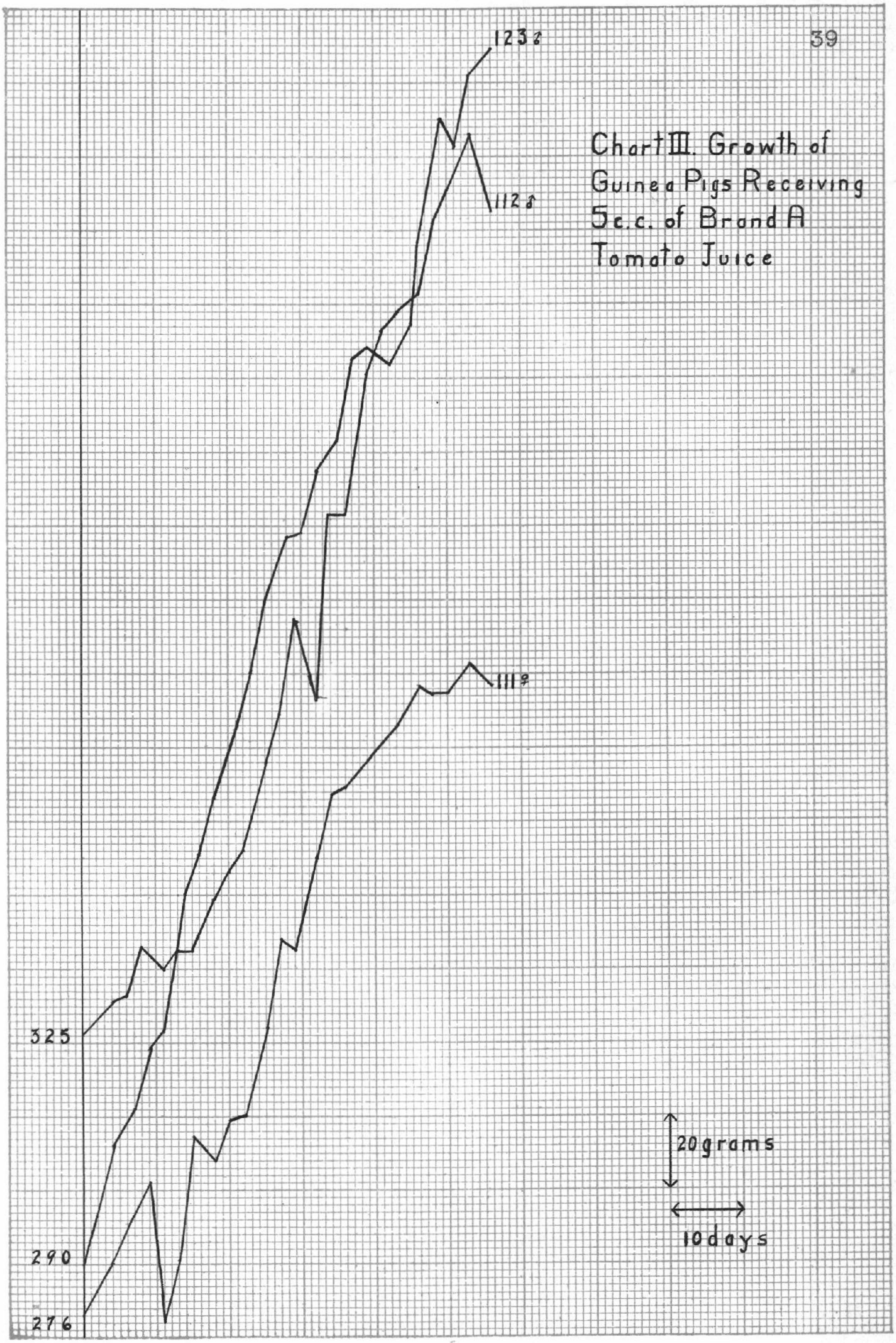
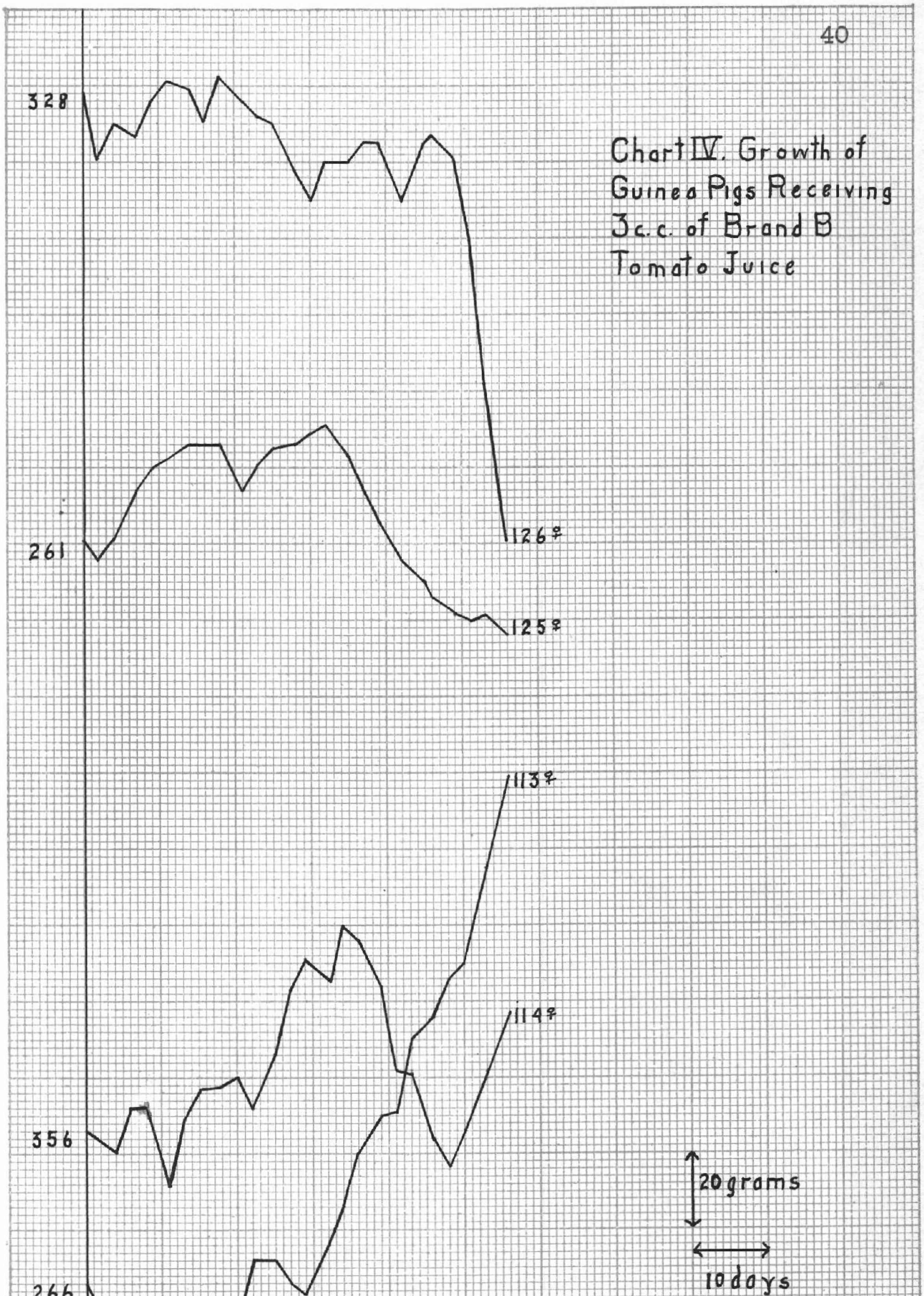


Chart III. Growth of Guinea Pigs Receiving 5 c.c. of Brand A Tomato Juice


328
261
356
266
126♀
125♀
113♀
114♀
Chart IV. Growth of Guinea Pigs Receiving 3c.c. of Brand B Tomato Juice
20 grams
10 days

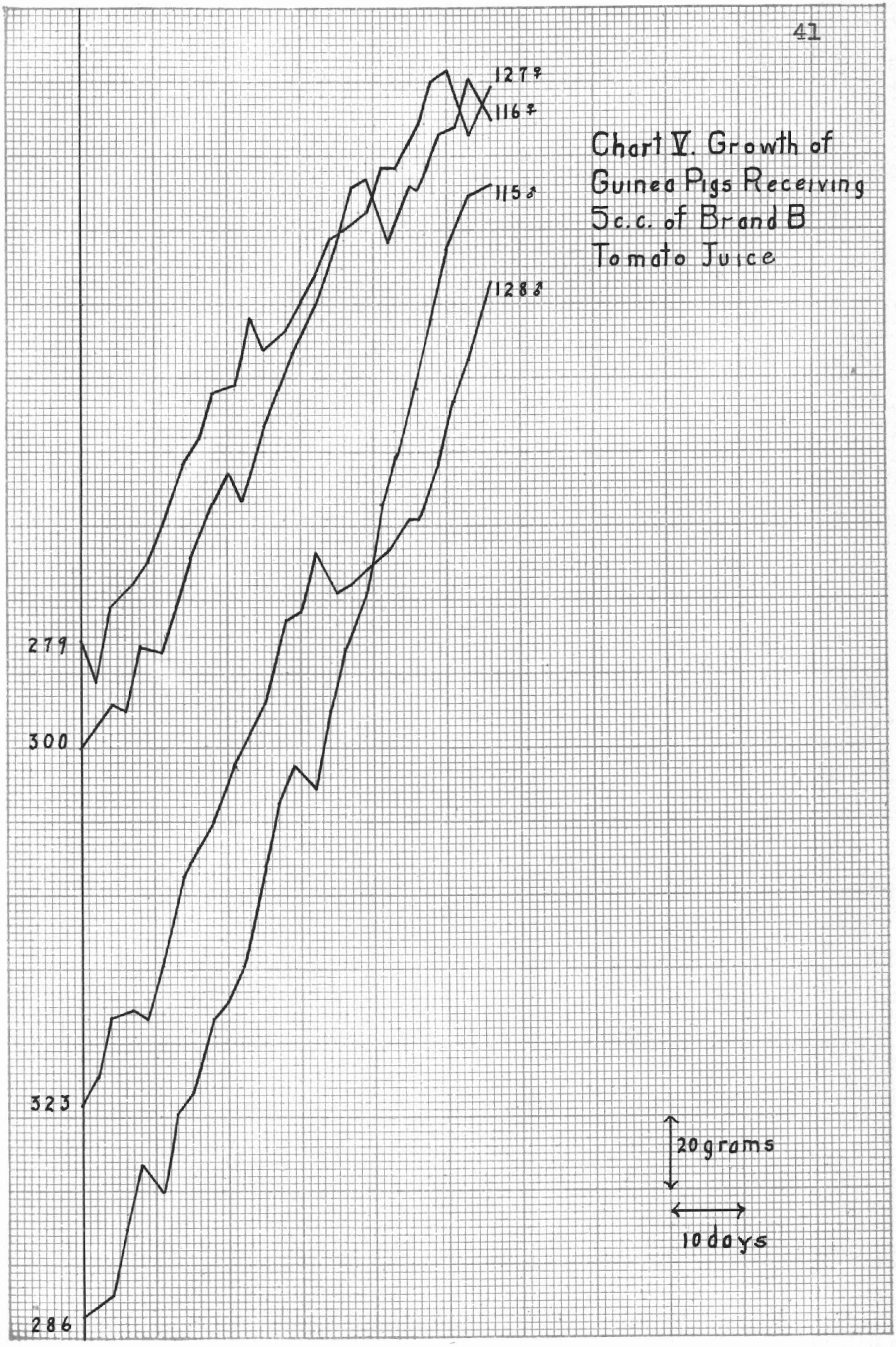


Chart V. Growth of Guinea Pigs Receiving 5c.c. of Brand B Tomato Juice

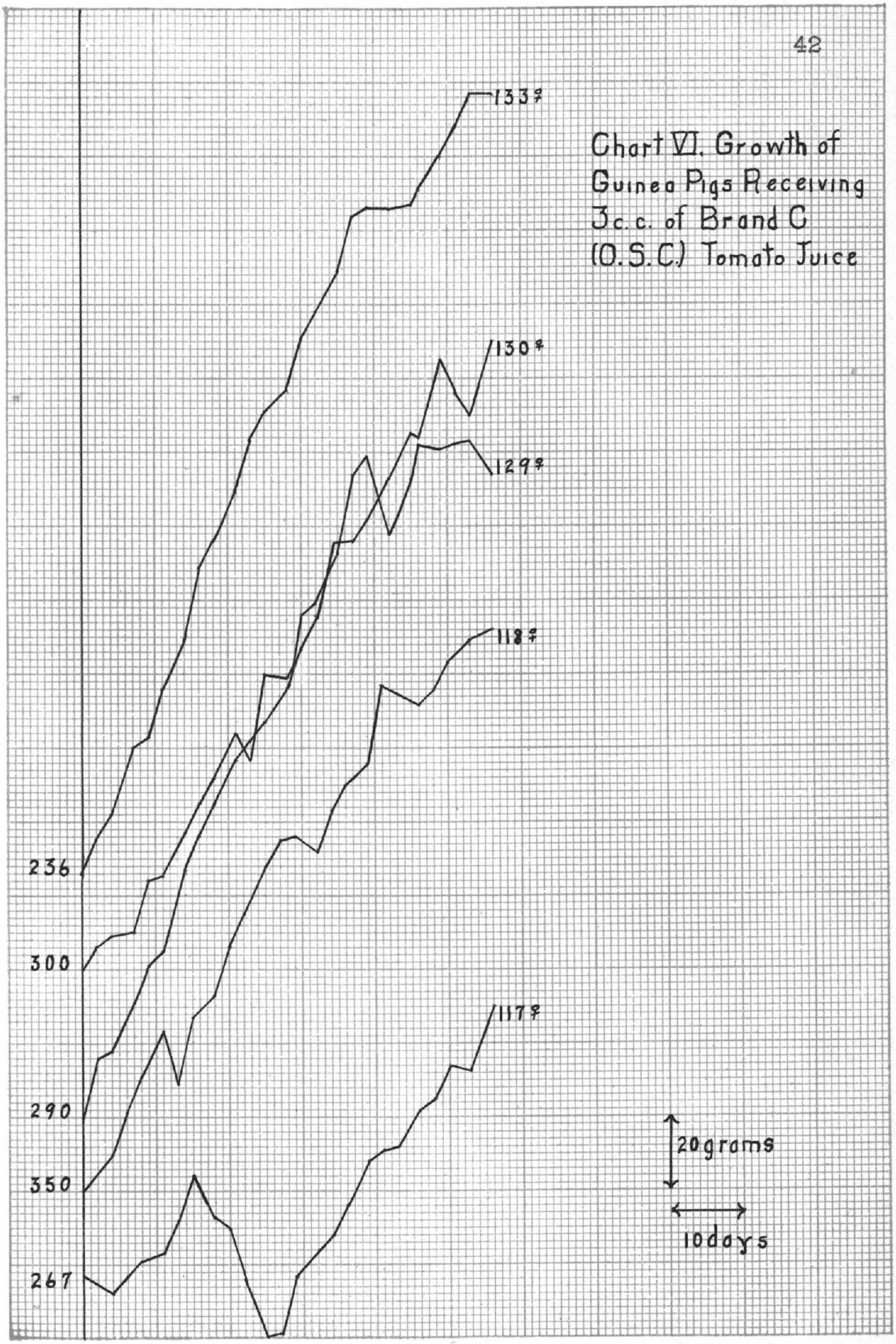


Chart VI. Growth of Guinea Pigs Receiving 3c.c. of Brand C (O.S.C.) Tomato Juice
133♀
130♀
129♀
118♀
117♀
236
300
290
350
267
20grams
10days

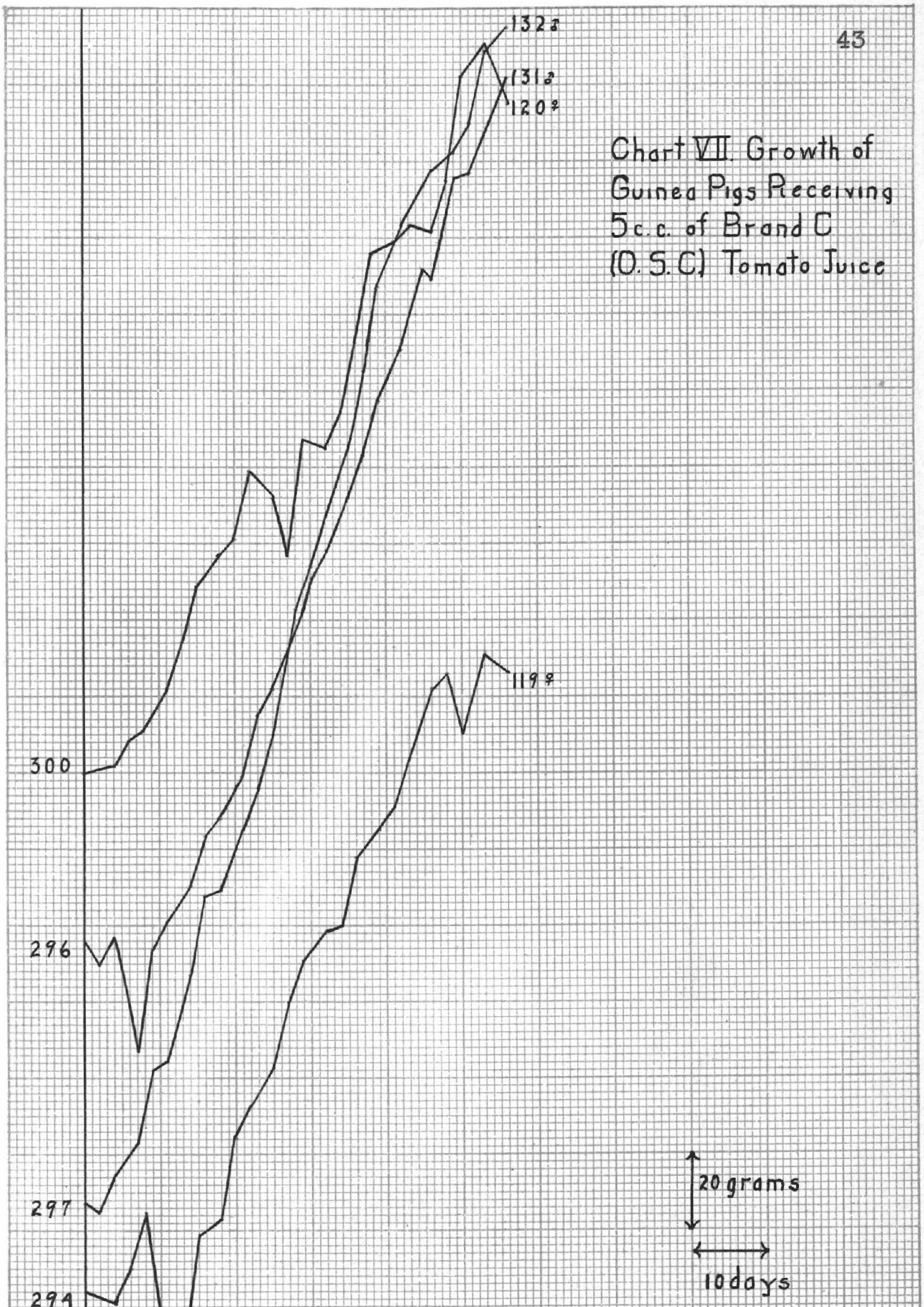


Chart VII. Growth of Guinea Pigs Receiving 5 c.c. of Brand C (O.S.C.) Tomato Juice

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