THE VITAMIN-C CONTENT OF FRESH SAUERKRAUT AND SAUERKRAUT JUICE[1]

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INTRODUCTION

There is a considerable amount of advertising before the public proclaiming the value of sauerkraut and sauerkraut juice as sources of the vitamins. Statements such as "contains all the vitamins" and "rich in vitamins A, B, C, and D" have been used, but these statements appear to be based upon general observations rather than upon experimental evidence. In some cases it is said that cabbage contains all the vitamins, and the inference is drawn that sauerkraut likewise contains all the vitamins. In view of the well-known instability of vitamin C, it appears legitimate to raise the question whether this vitamin is present in a product which has undergone such operations as are involved in the making and marketing of sauerkraut.

Some justification for the belief that sauerkraut must contain vitamin C is found in old reports regarding its use as an antiscorbutic agent on long sea voyages and the freedom from scurvy in certain regions where sauerkraut was extensively used as a food (*4, p. 45*).[2] But many other and often unobserved factors operate in such cases, and it is unsafe to place much reliance on these old reports.

A review of the literature seems to show only two pieces of experimental work on the vitamin-C content of sauerkraut. Ellis, Steenbock, and Hart (*3*), in their study of the stability of the antiscorbutic vitamin and its response to various treatments, include data on raw sauerkraut obtained from a local grocery. In this work they fed the sauerkraut at 2.5 and 5 gm. levels (daily) to guinea pigs on a scorbutic ration. On the 2.5-gm. level the animals died of scurvy within four to five weeks, while those on the 5-gm. level died in about six weeks. The conclusion of Ellis and his associates was that at these levels the sauerkraut showed no evidence of possessing antiscorbutic properties.

In a later paper, Wedgewood and Ford (*9*) report that sauerkraut juice in quantities ranging from 0.5 gm. to 5 c. c. per day did not prevent scurvy in guinea pigs. They are not very explicit as to how the sauerkraut was made, and it is therefore difficult to decide whether or not their sauerkraut can be taken as representative of the commercial product. Their work is also open to the criticism that the sauerkraut juice used may have lost its potency as a result of storage. The juice for the entire feeding period (26 to 33 days) was expressed from the sauerkraut at the beginning of the experiment and kept on

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[2] Reference is made by number (italic) to "Literature cited," p. 971.

ice until it was fed. Since the juice was not kept under anaerobic conditions, it is probable that, even if present at the beginning of the feeding period, vitamin C would have disappeared from the juice in the course of the experiment.

In view of the lack of experimental evidence available, it seemed desirable to make a study of the vitamin-C content of sauerkraut.

EXPERIMENTAL WORK

Two rations were used in this work. The first is a modification of that employed by Cohen and Mendel (*1*) and also by Parsons and Reynolds (*6*). The ration as given below has been used in this laboratory for the past three years and is called the soybean scurvy ration. Its composition is as follows: Soybean flour, 1,620 gm.; dried yeast, 120 gm.; purified casein, 105 gm.; calcium carbonate, 60 gm.; filter paper, 40 gm.; butterfat, 100 gm. The soybean flour was a commercial product the preparation of which involves heating. The yeast also was a commercial product and was a reliable source of the vitamin-B complex. The casein was purified by soaking for a week in water slightly acidified with glacial acetic acid (about 5 c. c. per 6 quarts of tap water). This water was changed every day. The filter paper was cut into small pieces and beaten in distilled water until a fine pulp was obtained. This was poured upon the mixed dry ingredients and the mass was rubbed until evenly mixed. When dry, it was ground and mixed thoroughly with melted butterfat.

The second ration is that used by Ellis, Steenbock, and Hart (*3*). It is called the alfalfa scurvy ration and contains the following: Alfalfa (autoclaved 30 minutes at 15 pounds pressure), 25 per cent; rolled oats, 69 per cent; purified casein, 5 per cent.

Animals that were used as positive or negative controls were given the above rations with the addition of 60 gm. of sodium chloride to the soybean ration and 1 per cent sodium chloride to the alfalfa ration. Animals fed sauerkraut or sauerkraut juice received their sodium chloride from these materials.

In the early part of the work both rations were used, but since the two rations were found to be quite similar from the standpoint of production of scurvy, only the alfalfa ration was used in the later experiments.

The protection of guinea pigs from scurvy was the method used in the investigation. After the preliminary feeding period described below, cabbage was removed from the diet and sauerkraut only was fed with the basal ration for a period of 60 to 75 days or until the animal died. The onset of scurvy symptoms, swollen wrists or a "jerky run," was noted and autopsy performed at the end of the experiment or after death.

On autopsy, the following signs of scurvy were looked for: Hemorrhages and swelling of the wrists or elbows of the fore legs and also below the hip joint of the hind legs; hemorrhages or bleeding at the costochondral juncture of the ribs, loose teeth, and any possible hemorrhages in the abdominal organs or in the peritoneum. The condition of the residue in the intestinal tract was also noted.

The weight of the guinea pigs when the cabbage was removed from the diet and sauerkraut feeding was begun varied from 211 to 276 gm., the average being about 240 gm. Young guinea pigs when received in

the laboratory or when taken from the mother were placed on the scurvy ration plus cabbage and allowed to eat ad libitum. With the first group of guinea pigs there was no preliminary feeding of sauerkraut before the experiment was begun, and difficulty was experienced in getting some of the animals to eat their portions. With all the other groups the following procedure was used: On the first day the basal ration plus cabbage only was fed; on the second day the cabbage was ground in a food chopper, a small amount (5 to 10 gm.) of sauerkraut was added to the cabbage, and the mixture was put into the basal ration. The sauerkraut was increased each day, but at no time was the amount of cabbage in the mixture less than 5 gm. per guinea pig in the group. In this way the guinea pigs gradually became accustomed to the taste of the sauerkraut, and as a general rule there was no trouble in getting them to eat it. When the experiment was begun each animal was placed in a separate cage, and the dose of fresh sauerkraut was mixed with the ration. The fresh sauerkraut juice was given to the animals by means of a medicine dripper.

The sauerkraut used in this experiment was made from All Seasons variety of cabbage, cut during the first week in November, 1927, and stored outside in a cool place for a week before it was made into sauerkraut. Three hundred pounds of shredded cabbage were mixed with 7½ pounds of salt and packed into 45-gallon barrels. A loose-fitting cover held down by a heavy weight was placed on top of the cabbage. These barrels of cabbage were allowed to ferment for 90 days at a temperature which ranged from 60° to 65° F. After this time the barrels were opened and the top sauerkraut, to the depth of 1 foot, was discarded. The sauerkraut was of good quality and possessed an acidity of 1.7 per cent calculated as lactic acid. Each day fresh samples were removed from points well below the surface, thus reducing or eliminating the factor of oxidation. The sauerkraut was ground in a food chopper and fed to the animals within as short a time as possible. The sauerkraut juice was obtained by putting the sauerkraut in a fine-meshed canvas bag and squeezing out the juice.

The study was made on three levels: Group 1 on 10 gm. of sauerkraut or sauerkraut juice daily; Group 2 on 5 gm. of sauerkraut daily; and Group 3 on 2.5 gm. of sauerkraut daily.

In the first group, three guinea pigs that failed to eat their portions were given partly neutralized sauerkraut in order to stimulate consumption. After the acidity of the sauerkraut had been determined, each day's sample was half neutralized with N/1 NaOH immediately before feeding. These animals (Nos. 4, 5, and 15) seemed to eat the partly neutralized sauerkraut better than the unneutralized. They were fed this type of sauerkraut throughout the 60 days of the experiment.

DISCUSSION OF RESULTS

HIGH LEVEL OF SAUERKRAUT AND SAUERKRAUT JUICE (10 gm.)

The first group of guinea pigs were fed 10 gm. daily of sauerkraut or sauerkraut juice. Inasmuch as Ellis, Steenbock, and Hart (*3*) reported no antiscorbutic value at 2.5 and 5 gm. levels, it seemed advisable to begin with the higher level in order to insure the detection of any vitamin C if it were present.

The individual weight curves (figs. 1 and 2) show that a 10-gm. level of this sauerkraut or the juice therefrom gave good growth and

complete protection from scurvy. The daily gain in weight of the 7 animals which received juice ranged from 2.26 to 5.33 gm. and averaged 3.83 gm. The figures for the 8 animals fed sauerkraut

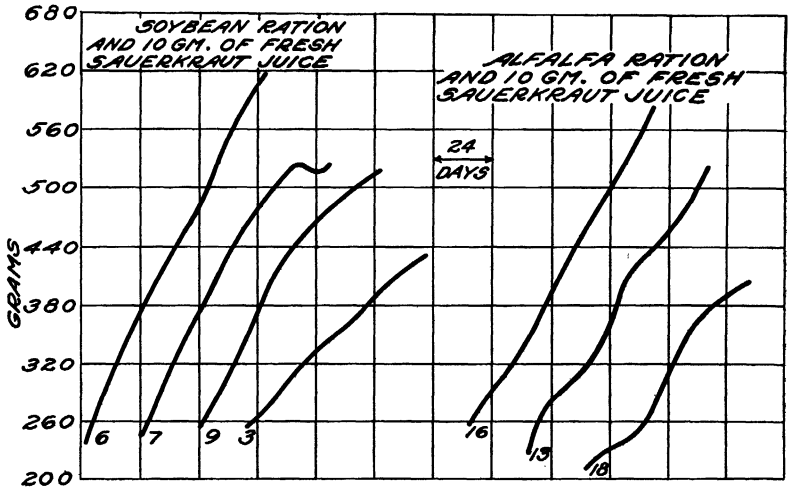

FIGURE 1.—Growth curves showing the antiscorbutic effect of 10 gm. of fresh sauerkraut juice daily when added to two scurvy rations fed to guinea pigs; autopsies at the end of 75 days disclosed no evidences of scurvy in any of the animals

ranged from 2.22 to 4.85 gm. and averaged 3.53 gm. The 2 animals which received 5 gm. of raw cabbage daily (fig. 4) made daily gains of 4.06 and 4.90 gm., respectively, and averaged 4.48 gm. Of the 15 animals fed sauerkraut or its juice at this level 6 grew faster than 1 of the animals (No. 11) that received 5 gm. of cabbage, and 3 made greater

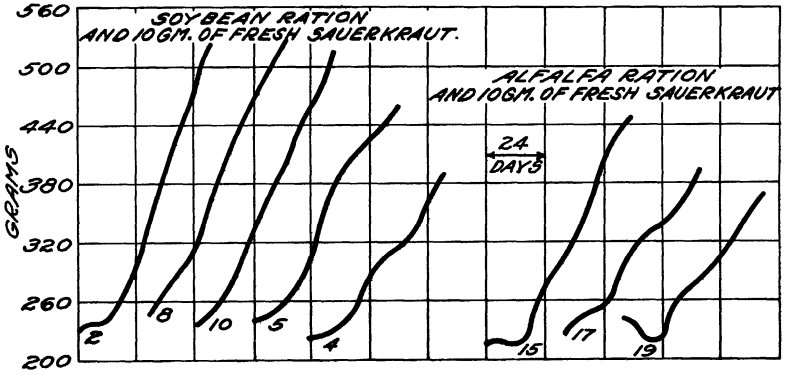

FIGURE 2.—Growth curves showing the antiscorbutic effect of 10 gm. of fresh sauerkraut daily when added to two scurvy rations fed to guinea pigs; autopsies at the end of 60 days disclosed no evidences of scurvy in any of the animals

daily gains than either of the positive controls. Because of the limited number of animals used as cabbage controls, too much emphasis should not be placed on the comparison, but it appears that 10 gm. of sauerkraut or sauerkraut juice contain about the same amount of vitamin C as 5 gm. of raw stored cabbage.

MEDIUM AND LOW LEVELS OF SAUERKRAUT (5 and 2.5 gm.)

When, after six to seven weeks, it was evident that the 10-gm. levels of sauerkraut and sauerkraut juice were each giving protection from scurvy and allowing good growth, feedings at 5 and 2.5 gm. levels

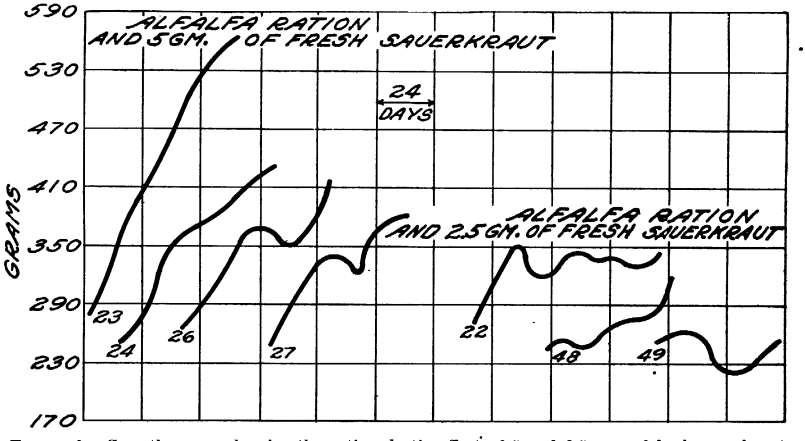

FIGURE 3.—Growth curves showing the antiscorbutic effect of 5 and 2.5 gm. of fresh sauerkraut daily when added to the alfalfa scurvy ration fed to guinea pigs. Autopsies performed at the end of 60 days on the animals fed at the 5-gm. level disclosed no evidences of scurvy in any case. An autopsy on animal No. 22 at the end of 75 days showed brittle leg bones; that on No. 48 at the end of 55 days, some swelling and muscular hemorrhage; that on No. 49, a slight swelling on one leg. These last three animals received but 2.5 gm. of fresh sauerkraut daily

were begun. Although growth on a 5-gm. level was not so consistently good as on the 10-gm. level, there was no evidence of scurvy. The daily gain in weight of the four guinea pigs receiving 5 gm. of

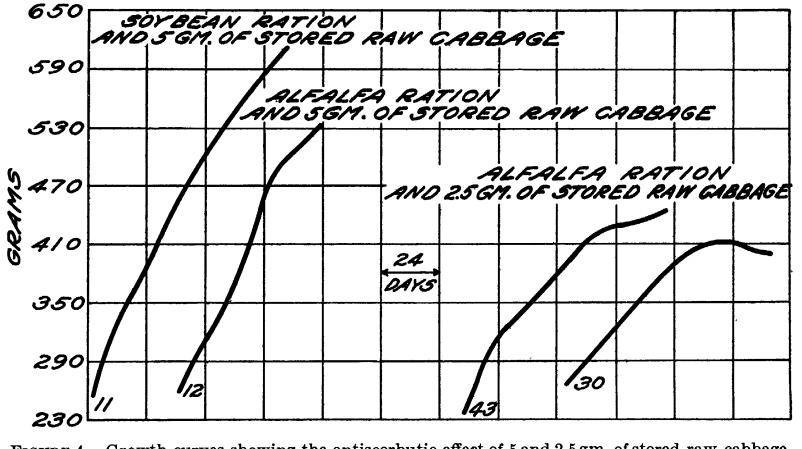

FIGURE 4.—Growth curves showing the antiscorbutic effect of 5 and 2.5 gm. of stored raw cabbage daily when added to two scurvy rations fed to guinea pigs

sauerkraut ranged from 2.33 to 4.97 gm. and averaged 3.30 gm. (Fig. 3.) This average gain is slightly lower than that for the animals on 10 gm. of juice or sauerkraut, but two of the guinea pigs, Nos. 23 and 24, have weight curves which are similar to many of the weight

curves of animals receiving 10 gm. of sauerkraut. It seems evident that a 5-gm. level of this sauerkraut was well within the protection level and also allowed good growth.

The growth on the 5-gm. level of sauerkraut was better than that obtained from one-half this quantity of cabbage. The gain per day on 2.5 gm. of cabbage (Fig. 4) was 2.92 gm. as compared with 3.30 on 5 gm. of sauerkraut. As already pointed out in the comparison of the higher levels of sauerkraut and of cabbage, the quantity of vitamin C in the sauerkraut was approximately equal to one-half of that contained in the cabbage.

Six animals were started on a 2.5-gm. level of sauerkraut, but only three of them lived through the experimental period. Three guinea pigs grew fairly well for 16 to 36 days, but at the end of this time there was a sudden drop in weight which was accompanied by a refusal to eat. The autopsy showed abnormal intestinal conditions. Guinea pig No. 22 was chloroformed at the end of 75 days instead of the usual 60 because of the several periods of loss and gain in weight of this animal. Although there were numerous fluctuations in the weight curve, it is evident that from the twentieth to the seventy-fifth day the animal was merely maintaining its weight. On autopsy, the leg bones were found to be very brittle and were easily fractured. Although there were no signs of hemorrhage, the brittle leg bones may have been due to a latent condition of scurvy.

Guinea pigs Nos. 48 and 49, also receiving 2.5 gm. of sauerkraut but started a month later than any of the other animals, were chloroformed at the end of 55 days because the sauerkraut was so nearly gone that satisfactory samples below the surface could not be obtained. Again, the weight curves (fig. 3) seem to indicate that 2.5 gm. of sauerkraut are needed for a maintenance level. Autopsy showed that with both animals there was slight evidence of scurvy.

Eddy et al. (*2*) consider 1 gm. of raw cabbage as the minimum protective dose. Unpublished data from this laboratory obtained by DeVilbiss showed that 1 gm. of raw cabbage added daily to Sherman's (*8*) basal diet would support life for 90 days, but the autopsy revealed brittle bones and teeth. In the present sauerkraut study 2.5 gm. of raw cabbage was the lowest level used. This level gave good growth for 44 to 58 days, and after that time the weight curve flattened off. (Fig. 4.) If 1 gm. of raw cabbage is considered to be the minimum protective level, with perhaps slight signs of scurvy, and 2.5 gm. of fresh sauerkraut the minimum level although not completely protective, it appears that approximately one-half of the vitamin-C content of cabbage may be destroyed in the process of making sauerkraut.

The experiments of Ellis, Hart, and Steenbock (*3*) showed a much greater destruction of vitamin C than is indicated in the present studies. These authors, however, used bulk sauerkraut obtained from a grocery store. It is probable that much of the vitamin-C content was lost after the sauerkraut was taken from the fermentation vat and repacked. As it frequently takes several weeks for a grocer to market a barrel of sauerkraut, it is not improbable that the vitamin-C content of the sauerkraut was lost by exposure to the air during the period of retailing.

That oxidation and not fermentation is the important factor in the destruction of vitamin C was shown later in the same laboratory

by Lepkovsky, Hart, Hastings, and Frazier (*5*). Sterile orange juice and tomato juice kept in test tubes plugged with cotton showed marked deterioration in 7 and 24 days, respectively. If air was excluded by means of vaseline plugs the juices retained their potency. Likewise, if the tomato juice was sealed with vaseline plugs and fermented with bacteria, some of which are characteristic of sauerkraut, the juice was still effective in the cure of scurvy. An earlier paper by Zilva (*10*) showed that the sugars present in lemon juice could be removed by yeast without appreciably altering the vitamin-C content of the juice.

It is not improbable that the strictly fermentation processes which take place in the formation of sauerkraut tend to prevent the destruction of vitamin C. In a recent paper Pruess, Peterson, and Fred (*7*) report that the gases formed in the fermentation are nearly 100 per cent carbon dioxide. The oxygen incorporated in the shredded cabbage at the time it is placed in the vat is probably speedily consumed by the respiration of the plant cells or removed from the mass by the carbon dioxide formed by the plant cells and bacteria. However, a trace of oxygen seems to persist in the sauerkraut throughout the fermentation and the partial destruction of vitamin C is probably due to this rather than to the specific action of the microorganisms.

The authors wish to point out specifically that the presence of vitamin C in the sauerkraut used in the present study does not warrant the assumption that sauerkraut as it reaches the consumer contains vitamin C. Indeed, the experiments of Ellis, Hart, and Steenbock (*3*) show that in some instances it does not. Whether or not canned sauerkraut or commercial sauerkraut juice contains vitamin C can be decided only by carefully controlled experiments that deal directly with these products.

PRESENCE OF VITAMIN C DEMONSTRATED BY RECOVERY TYPE OF EXPERIMENT

Two guinea pigs in the "negative" group, Nos. 32 and 67, were given 5 c. c. of sauerkraut juice at the onset of definite scurvy symptoms. (Fig. 5.) The juice was fed for 16 days and autopsies were performed on the animals on the seventeenth day. The autopsies indicated in both cases that the animals were practically cured of scurvy. Although the protection method was used primarily in this study, the above-mentioned data on the recovery of two of the "negative controls" strengthen the conclusion that an appreciable quantity of vitamin C was present in this sauerkraut juice.

SUMMARY

This study shows the vitamin C content of fresh raw sauerkraut and sauerkraut juice, i. e., material which was fed immediately after being taken from the barrel in which it was fermented. The sauerkraut was fed at levels of 10, 5, and 2.5 gm. daily for each guinea pig for approximately 60 days, and sauerkraut juice was fed at a level of 10 gm. for 75 days. Positive control animals were fed at 5 and 2.5 gm. levels of raw stored cabbage.

The 10-gm. level of either fresh sauerkraut or fresh juice protected from scurvy and allowed good and in some cases excellent growth. The growth curves are comparable to those of guinea pigs receiving

5 gm. of raw stored cabbage. The 5-gm. dosage of fresh sauerkraut was well within the protection level and also allowed good growth. The 2.5 gm. level of fresh sauerkraut was probably not quite enough to protect from scurvy, although a maintenance of weight was obtained. The 2.5 gm. level of raw stored cabbage allowed good growth for 44 to 58 days, and after that time the weight curve

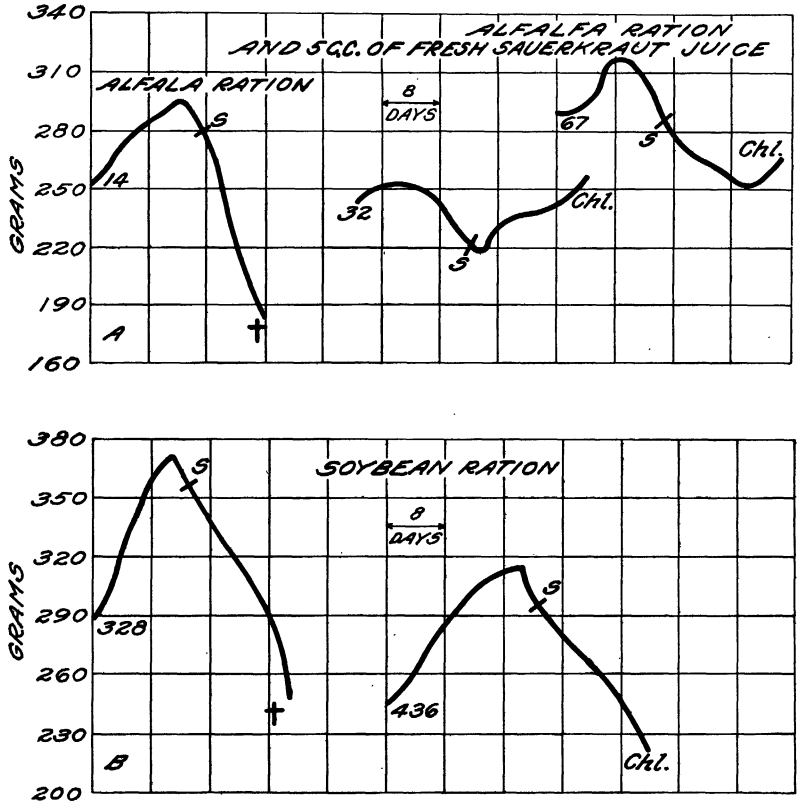

FIGURE 5.—Growth curves of guinea pigs receiving only the basal scurvy-producing rations. Definite symptoms of scurvy were present at points marked "S"; + indicates death and Chl. indicates that the animal was chloroformed. A, These animals were on the alfalfa scurvy ration. Nos. 32 and 67 were given a recovery dosage of 5 c. c. of fresh sauerkraut juice daily; autopsy at the end of a recovery period of 16 days disclosed that recovery was complete. Animal No. 14 was a "negative control" receiving no addition to the basal diet and showed, on autopsy, characteristic evidences of scurvy. B, These animals were on the soybean scurvy ration and, at autopsy, showed the characteristic evidences of scurvy

"flattened off," although there was no evidence of scurvy. A loss of vitamin C in the formation of sauerkraut is thus definitely demonstrated. This loss is approximately one-half of the vitamin-C content of cabbage.

Guinea pigs which had developed definite symptoms of scurvy recovered when fed 5 c. c. of fresh sauerkraut juice daily.

No conclusions as to the probable vitamin-C content of commercial sauerkraut are warranted by these experiments.

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