154. THE ASCORBIC ACID CONTENT OF DRIED VEGETABLES

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IN Kenya there is a multitude of climates, from humid tropics to eternal snow, from rain forests to desert. The problem of providing an adequate supply of fresh vegetables might thus appear simple, but the distance dividing the cool temperate zones, suitable for vegetable production, and the semi-arid to desert zones is great. The transport of fresh vegetables is not always easy and wastage is heavy. The use of dried vegetables seemed worth exploring; they are easy to transport and, if properly prepared, palatable. The problem was placed before us and we were asked to take into consideration two criteria—palatability and vitamin C content. There was little information of previous work at our disposal so the problem had to be undertaken as a subject of initial research employing the knowledge gained in pyrethrum drying.

When the problem was first propounded we were interested only in rations for the native population. One of the most popular of the local green vegetables being the young leaves of the cowpea (*Vigna catjang*), this material was used in our preliminary experiments. The leaves were dried in the sun and by artificial methods. The results were not too encouraging. (For method of estimating ascorbic acid see below.)

Table 1. *Ascorbic acid content of fresh and dried cowpea leaves*

	mg./100 g.	Calculated to fresh weight
Fresh leaves	13.2	—
Sun-dried	15.6	2.5
Artificially dried	33.8	5.5

Although these figures are not strictly comparable they were sufficient to decide us against attempting to produce dried vegetables by sun-drying only. A further experiment was made in a drier. Fresh leaves containing 70 mg. ascorbic acid per 100 g. gave 16 % of dry material, containing 237 mg. ascorbic acid per 100 g., a loss of 46 %: apparently artificially dried cowpea leaves would be a good antiscorbutic. There remained the other test, that of palatability; the dried cowpea leaves were cooked at the labour camp at these laboratories in the normal native manner. The report was that the material was quite edible but very hard and fibrous. Apparently, during drying, the vascular bundles undergo an irreversible change and are no longer capable of absorbing water and becoming soft. This is not an insuperable difficulty but is certainly a grave disadvantage.

Experiments were now extended to kale, not because it was a likely vegetable but because a supply was readily available and it is a type of crucifer. The experiments were really intended to ascertain the most suitable temperature for artificial drying. Results of the first series are given in Table 2.

Table 2. *Effect of temperature and time of drying on kale*

Temp.	45-48°	53-55°	60-65°
Ascorbic acid in fresh, mg./100 g.	173	147.5	181
Loss of weight in drying, %	79.3	83.5	79.5
Time of drying, hr.	9	4	3
Ascorbic acid in dry, mg./100 g.	295	196	170
Loss in ascorbic acid, %	65	77.5	81

In this series of experiments the rates of loading in the drier employed were practically identical. Although drying at a lower temperature is protracted, the oxidation of ascorbic acid is much less than at the higher temperatures. Other experiments on the same material gave comparable results, but more important was the indication that, in such experiments, uniformity of technique is essential. In the second series of experiments the destruction of ascorbic acid was over 90 %, this great loss being attributable to bruising during preparation.

Further work was done on lucerne. Dried lucerne was found to contain a large amount of ascorbic acid [Levy & Fox, 1935] but here too the dehydration of the vascular bundles gave a very fibrous cooked material. Although these preliminary experiments were conducted upon what appeared to be quite suitable and very easily obtained vegetables, there were several reasons why others should be examined. The main objection against cowpea leaves was the development of the hard fibre, which definitely reduced palatability. Work was not continued on lucerne because of observations made in South Africa that lucerne was liable to cause digestive disturbances. Kale was omitted because of the difficulty in handling it.

Most, if not all, European vegetables can be grown in the highlands of Kenya. Most of these are suitable for drying, but there are reasons for not using them all. For example, asparagus grows to perfection but it takes time to grow and is always a luxury product.

Experimental

The type of drier employed in the early stages of these experiments was a cylindrical electrically heated one provided with thermostatic control, having a single tray of 1 sq. ft. area; the draught was comparatively low, being supplied by a chimney 4 ft. high. Distribution of heat in this drier is rather uneven, and the material being dried requires constant attention. Later, a model drier of the type employed for pyrethrum drying [Beckley & McNaughtan, 1937] was built. This drier is square with 3 ft. sides and carries 6 trays. Heating is electrical, thermostatically controlled. Ventilation is secured by means of a 6 in. pipe, 80 ft. long; later this was augmented by a small electric fan. On the whole, heat distribution in this drier is fairly regular but on days of high wind, fluctuations in the distribution of heat occur, although the drier is indoors.

In the course of experiments conducted on the full scale, it was decided to change to a tunnel drier. Logically, therefore, laboratory scale experiments should also have been made on a tunnel drier. Previous investigations on a different subject, however, demonstrated that it is very difficult to build an efficient model tunnel type drier. However, the experience gained in full scale experiments, to be reported later, showed that the effects obtained in the model drier used by us are not very different from those obtained in a full-size tunnel drier.

Ascorbic acid was assayed by titration with indophenol-2:6-dichlorophenol solution. A 3 % solution of metaphosphoric acid was employed in grinding and,

where liquids were concerned, such as the water obtained in cooking the vegetables, the final concentration was made up to 3 % by the addition of the requisite quantity of 20 % metaphosphoric acid.

Cabbage. The preparation of cabbage for dehydration consists in cutting it into shreds $\frac{1}{4}$ to $\frac{1}{2}$ in. in width. In view of the effect of metals upon the ascorbic acid oxidase an experiment was conducted to ascertain the effect of using ordinary steel and stainless steel knives for shredding, upon the ascorbic acid content of dried material. A small cabbage was halved using a stainless steel knife and the core carefully removed. One-half was shredded with a stainless steel knife, the other with an ordinary knife, and equal quantities of the shredded material immediately transferred to the drier. A single tray divided along the middle was used for both lots. In order to ensure that each half received similar treatment the tray was turned at intervals. The moisture contents of the two lots, 6.08 % and 6.11 %, show that drying in the two halves was very even. The dried cabbage shredded with a stainless steel knife had an ascorbic acid content of 478 mg./100 g.; that shredded with an ordinary knife assayed at 302 mg./100 g. Because of this big difference stainless steel knives were employed throughout the subsequent work.

Normally, cabbages come from the field with a fair number of outer green leaves. Some of these are very coarse and not suitable for food. In addition, the outer leaves are not easily shredded by hand, for which reason in our very early experiments the firm heads only were used. This gave a great deal of waste; when in one case the waste reached 70 % of the original weight, we were led to investigate the distribution of ascorbic acid in a head of cabbage. Good firm cabbages were taken and only the very coarse outer green leaves were discarded. The outer leaves contained by far the highest relative proportion of ascorbic acid, followed by the core and the small heart leaves. The tender white inner leaves contained very much less. This observation is confirmed by Robinson & Courtice [1940]. The results of three experiments are given in Table 3.

Table 3. *Distribution of ascorbic acid in the cabbage, mg./100 g.*

Outer green leaves	85.7	63.0	104.6
Curled green leaves	68.9	49.4	55.2
White leaves of head	45.2	46.0	32.5
Heart leaves	78.0	65.7	55.0
Core	77.9	66.3	56.7

As a result of these experiments all the outer leaves which appear to be sufficiently tender are now to be included in the material to be shredded and dried. On the large scale the shredding machine will do this easily.

From information which reached us it appears that in preparing cabbage for drying it is usual to blanch the shredded material in live steam for a couple of minutes. Such treatment by killing the tissues speeds up drying. It is also claimed—quite probably correctly—that this preliminary steaming destroys the oxidases and so reduces the loss of ascorbic acid.

The results of one of our experiments to ascertain how blanched dried material compares with unblanched dried material are given in Table 4.

The dried blanched material contains about 20 % more ascorbic acid than does the dried unblanched material. In cooking too there is a marked difference. The cooking water from the dried unblanched material contains 19 % of the original content, while the solid contains only 12.6 %, a loss during cooking of 68.4 % of the ascorbic acid in the original material. The cooking water of the blanched material contained 28.9 % and the drained solids 16.8 % of the original

Table 4. *Effect of blanching on ascorbic acid content of dried cabbage, mg./100 g.*

Fresh cabbage	63.0
Unblanched dried, boiled 30 min. after soaking	332.5
Cooking water	63.3
Cooked solid	41.8
Blanched dried, boiled 30 min. after soaking	406.7
Cooking water	117.4
Cooked solid	68.4

content. The loss in cooking in this case is only 54.3 %. A further advantage is that the cooked solid from the blanched material contains half as much again ascorbic acid as that from the unblanched material. As far as ascorbic acid is concerned blanching is definitely desirable. The ascorbic acid content is not the sole criterion; palatability of the final product must also be taken into account. On soaking, blanched material absorbed six times its weight of water, unblanched material four times. The soaked material was then cooked for 30 min. Perhaps the time of cooking may appear excessive but all these experiments have been conducted at an altitude of 5800 ft., where cooking takes longer than at sea level. Throughout the cooking the material was tested at intervals with the point of a glass rod. Partially cooked blanched material at 20 min. looked very attractive, but after a full 30 min. a very marked change in appearance had occurred; the green remained, but looked artificial, the white portions assumed a greyish tint while the whole was reduced to a mere mush, unattractive in appearance and most unpalatable. The unblanched material under exactly the same conditions was crisp, most attractive in appearance and indistinguishable from well cooked fresh cabbage.

The very great loss of ascorbic acid during the soaking and cooking of the unblanched dried material is a very grave disadvantage. In such material of course the oxidases are not destroyed and during the period of soaking would act upon the ascorbic acid. That this is so is demonstrated by the results of experiments, one of which is given in Table 5, in which soaking followed by boiling was compared with dropping the material directly into vigorously boiling water. In another experiment the loss after soaking and cooking was 64.5 %, after boiling only 39.6 %. There is no doubt that immediate boiling has prevented the destruction of ascorbic acid.

Table 5. *Effect of soaking before boiling on ascorbic acid content of dried unblanched cabbage, mg./100 g.*

Dried cabbage, boiled only	434.2
Cooking water	186.3
Cooked solid	176.8
Loss in cooking	16.4 %
Soaked and boiled:	
Cooking water	83.3
Cooked solid	52.0
Loss in cooking	68.9 %

As regards palatability there was no difference either in appearance or in taste between the two lots of cabbage. With cabbage, therefore, there is no need for preliminary soaking.

It would appear that the preparation of cabbage for dehydration is a simple matter. In a full scale experiment where a ton of cabbage was treated, the final product contained 194 mg. ascorbic acid/100 g., quite a satisfactory figure considering that the material was cut up by inexperienced labour. Material produced

by a local farmer, who was very keen to embark upon the drying of vegetables, contained only 35 mg./100 g. There are two possible explanations of this very low content. Blunt knives may have been used causing bruising, or the shredded material may have been stored for some time before being placed in the drier. That this is a serious matter is shown by the following figures: some shredded material which contained 55.4 mg./100 g. contained only 30.8 mg./100 g. after being left for 5 hr., a loss of 45 % of the ascorbic acid content.

For the full scale production special machinery is being ordered in which the cutters are all stainless steel, and very great care will be taken that cabbage in the shredded condition will not stand more than a few minutes before going into the drier.

To obviate criticism that palatability trials had been confined to members of the laboratory staff fair-sized samples were sent to a number of people living at a distance. In every case they reported that the material was excellent and most palatable. In one case the sample was 3 months on the road and subjected to all sorts of climatic conditions.

Cauliflower. In view of the unexpected distribution of ascorbic acid in the cabbage a similar study was made on the cauliflower. Again the highest content was found in the outer leaves and in the innermost stalks. The results of an experiment are given in Table 6.

Table 6. *Distribution of ascorbic acid in the cauliflower, mg./100 g.*

Outer leaves	83.9
Outer 'flowers'	65.2
Stalks of outer 'flowers'	63.8
Inner 'flowers'	48.0
Stalks of inner 'flowers'	70.5

Since normally the outer leaves of a cauliflower are more tender than the outer leaves of a cabbage, it will be possible to include a very fair proportion of the outer leaves in the dried product without rendering it stringy and unpalatable. The presence of a certain amount of leaf in the dried material also tends to improve its appearance. In all our experiments, therefore, a fair quantity of the more tender leaves has been included. Instead of breaking up the head, the trimmed cauliflower has been cut into thin slices. This procedure makes preparation easier when working on the full scale.

Here, too, the question of blanching arises. In our first experiments on cauliflower the material was dried without blanching. Drying took 23 hr. and the yield was 10.6 %. The fresh material contained 79.4 mg. ascorbic acid/100 g.; the dried material 289.8 mg./100 g. The dried material was brownish but absorbed water well, regaining a close approximation to its original appearance. Because of the protracted drying, blanching was tried to ascertain if killing the tissue would speed up drying. Blanched material was found to dry in 11 hr. and gave a yield of 10.4 %. The marked shortening in the time of drying decided us to make blanching the regular practice. Experiments soon showed that the optimum period for blanching was 4 min. exposure to live steam; a shorter exposure did not suffice to kill the tissue, while longer exposure tended to cook the material and cause a loss of soluble constituents.

In the earlier experiments no trouble was encountered in drying, a temperature of 55° being used. A demand, however, came for the production of a large quantity of dried cauliflower and the trays in the drier were rather heavily loaded. Drying was most uneven and where it was prolonged a bad-smelling slime developed on the moist surfaces. A large motile bacterium was isolated

from the slime in almost pure culture by Dr R. M. Nattrass, Senior Plant Pathologist at these laboratories, to whom our thanks are due. At first it was thought that the organism must of necessity be thermophilic, but it developed rapidly at room temperature, both on artificial medium and on potato. Apparently, although the temperature of the air current in the drier was 55°, this temperature was not attained on the attacked surface. Perhaps rapid evaporation from contiguous surfaces had prevented the temperature from rising. Raising the temperature in the drier to 65–70° prevented bacterial action as long as the rate of loading of the trays was not excessive. As soon as the trays were too heavily loaded, even at these temperatures, some of the cut surfaces were shielded from the air current and on the wet surfaces the bacterium rapidly developed.

Before cooking the dried cauliflower it was found necessary to soak for at least 30 min., preferably longer. If soaking were curtailed, the tissue did not absorb water properly and the cooked material had a most unappetizing appearance. It was also tough. With full soaking, the cooked material closely resembled fresh cauliflower in appearance. Although the plain dried material gave on cooking a product of excellent appearance, the blanched material was even better. The flavour too, was perfect.

As far as ascorbic acid is concerned results are not quite so satisfactory. There is a heavy loss of ascorbic acid, probably occurring during the period of soaking. Results of two typical experiments are given in Table 7.

Table 7

	Plain dried mg./100 g.	Blanched and dried mg./100 g.
Fresh cauliflower	79.4	71.3
Dried cauliflower	289.8	462.0
Cooked after soaking:		
Solid	17.3	64.2
Cooking water	20.7	62.1

Probably the heavy loss in the cooking of the unblanched material is due to the action of oxidases during the soaking.

Carrots. Although it is well known that the vitamin C content of carrots is comparatively low (in our experiments this fluctuated about 9 mg./100 g.) they have been included in the vegetables to be dried on account of their high food value and value as a source of other vitamins.

The distribution of ascorbic acid in the carrot was investigated. Tips contained 8.6 mg./100 g., the middle portion 8.6 mg., and the butt end, after discarding the absolute butt, 11.6 mg. This was perhaps to be expected as the butts are often coloured green to the depth of 1 cm.

The preparation of carrots for drying is very simple. With young carrots there is even no need for peeling but with more mature material this is desirable. The cleaned and topped carrots are either sliced into circles or cut into strips. Drying is done at 150° F. and is complete in 8–10 hr. The yields of dry material obtained in a number of experiments lay between 13 and 14%. Here, too, the question of blanching was studied. The sole effect of blanching was to give a lower yield, in one experiment from 13.3 to 12.1%, while on cooking the flavour of the blanched material was flat.

Green beans. In the preparation of beans for cooking the waste is comparatively small so it did not appear necessary to investigate the distribution of ascorbic acid, but the variation with age was studied. Very young beans had a

content of 19–19.6 mg./100 g. More mature pods, in which the strings were beginning to form, contained 24.7–26 mg./100 g.; older beans 24.1–26.2 mg./100 g.; very old beans had a content of 27.7–29.4 mg./100 g. Thus, in maturation there is not a sufficient increase in ascorbic acid to make it worth while processing old beans which would require a great deal of manual labour in ‘stringing’. Beans up to the stage where the strings become evident will therefore be used for the production of dried vegetables. Such beans will need cutting into strips only. The drying temperature to be employed is 130° F. The yields of dried beans obtained in several experiments varied from 10.6 to 12.5 %. Here, too, the effect of blanching was investigated, a steaming time of 3 min. being used. Blanching depressed the yield of dry material by 1.5 %. The ascorbic acid content of blanched dried beans was 74.5 mg./100 g., while that of a parallel lot dried without blanching was 95.1 mg. The colour of the dried blanched beans was a faded yellow-green, whereas that of the unblanched dried beans was a good green with a silvery tint. On cooking, the difference in colour was even more marked; the blanched beans were tough, hard and of a brown colour, while the unblanched were quite normal in texture and of a green colour. The flavour of the unblanched was distinctly better. Unexpectedly, blanching also had a very deleterious effect on the ascorbic acid content. A well-mixed lot of fresh beans was divided into two; one-half after cutting was blanched and dried, the other dried without blanching. The dried products were carefully sampled and cooked in duplicate quantities with and without pre-soaking. The results of this experiment are given in Table 8.

Table 8. *Effect of blanching and pre-soaking on ascorbic acid content of cooked dried green beans*

	Blanched mg./100 g.	Unblanched mg./100 g.
(1) Unsoaked:		
(a) Solid	35.9	53.2
Cooking water	30.9	74.2
(b) Solid	26.0	32.2
Cooking water	31.6	61.8
(2) Soaked:		
(a) Solid	13.4	13.0
Cooking water	13.0	11.1
(b) Solid	14.8	9.9
Cooking water	14.2	6.2

A further test was made on the palatability of cooked beans with and without pre-soaking and it was found that there was no difference in flavour; the recommendation has therefore been made, as with cabbage, that dried green beans should not be pre-soaked but dropped straight into boiling water.

Potatoes. Probably the best known method of drying potatoes is the production of potato flakes, but it was felt by all concerned that potatoes in this form would very soon become monotonous as an article of diet. What is really required is some form which can be prepared in different ways. Plain sliced potatoes do not boil up well but fairly massive chips can be both boiled and fried, and this form has therefore been employed in all the experiments.

Because of the danger of discoloration after cutting, it was considered essential that potatoes should be blanched. In course of the experiments to determine the optimum time of blanching some more unexpected results were obtained. Blanching for a period of 60 sec. in live steam sufficed to prevent discoloration

and the dried material was quite attractive; it was fairly white and the individual chips were opaque. However, on attempting to boil this dried material, the real problem was encountered. Even after soaking overnight and cooking for 1 hr. the material did not soften. Increasing blanching periods were tried but, until the time of 3 min. was reached, this trouble continuously occurred.

Occasionally, the material after being steamed for less than 3 min. tended to turn brown, but this did not occur in that blanched for 3 min., unless a long time elapsed between steaming and entry into the drier. Drying was fairly fast, 8½–10 hr., at a loading of 2–3 lb. per sq. ft. When properly treated, the dried material was translucent and had a pale yellow colour. The sides of the chips were deeply concave.

In the first experiments on cooking, the dried chips were soaked overnight, absorbing approximately double their own weight of water. Cooking was complete after 25 min. The colour of the cooked material was perfect and whether eaten whole or mashed the flavour was practically indistinguishable from that of the fresh potato. In one or two cases the opinion was expressed that the flavour was rather more pronounced than that of the fresh potato. Potatoes soaked overnight were also fried, giving a product indistinguishable in every respect from fried fresh potatoes. It was later ascertained that the minimum soaking required to obtain a passable product is 2 hr.; this is rather too short for a perfect product as the chips do not soften fully.

The dried material shows no tendency whatsoever to absorb water from a wet atmosphere. A sample has been left standing about in the laboratories in an open bag for 7 months, the last of which was very wet. The dried chips were as hard as they were on the day they were prepared and cooked up perfectly, whether boiled or fried. Although during the experimental work the ascorbic acid content of the dried material was not considered, an assay was made on the 7 months-old material. The ascorbic acid content was 49 mg./100 g., so dried potatoes can make a useful contribution to the vitamin C requirements.

SUMMARY

Studies were made of the ascorbic acid content and palatability of dried vegetables, including cabbages, cauliflowers, beans, carrots and potatoes.

Details of methods used are described. Potatoes and cauliflowers should be blanched before drying; while carrots, green beans and cabbages should be dried without previous blanching.

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