THE EFFECT OF DRYING AND OF SULFUR DIOXIDE
UPON THE ANTISCORBUTIC PROPERTY
OF FRUITS.*

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The most important antiscorbutic foods are now known to be
the fruits and vegetables, and it is usually considered that these
foods are chiefly, if not only, valuable for this property when used
fresh. Holst and Fröhlich (1) showed that cooking and canning
or drying greatly decreased the antiscorbutic value of a variety
of foods. Since the danger of scurvy is greatest under those cir-
cumstances under which an adequate supply of fresh foods is apt
to be difficult to obtain, much interest has always attached to the
effect of various methods of preservation upon the vitamin C
content of foods. Numerous studies have been made upon the
citrus fruit juices, cabbage, milk, potatoes, tomatoes, and a few
other fruits and vegetables. In general as indicated by the work of
Harden and Zilva (2), Hess and Unger (3), Givens and McClugage
(4), and Goss (5), a large proportion of the vitamin is preserved in
citrus products dehydrated by suitable means, particularly in
vacuo and at relatively low temperatures. Most of these studies
have been made upon laboratory products, but a few have dealt
with commercial specimens (Goss (5) and Humphrey (6)).

A number of tests of dried cabbage has been made by Holst and
Fröhlich (1), Cohen and Mendel (7), Delf and Skelton (8), and
Ellis, Steenbock, and Hart (9), with varying results, the vitamin
being more or less decreased even when the cabbage was dried
in carbon dioxide, if the temperature exceeded 65°. The work of

* Published with the consent of the Director of the California Agricul-
tural Experiment Station. This investigation was suggested by A. W.
Christie formerly in charge of fruit drying investigations at this station.
Hess and Unger (3) with dried carrots and dried prunes indicated also quite complete loss of the antiscorbutic property during drying, although detail of method of drying was not described. Disappointing results were reported by Givens and McClugage (4) with dried potatoes, and by Chick, Hume, and Skelton (10), and Shorten and Ray (11), with various dried fruits and vegetables. The latter investigators report that tomatoes retain a good deal of the vitamin after being sun-dried, potatoes and cabbage some, but that carrots, spinach, turnips, and various leaves, lose all.

Apparently the more acid foods, such as the citrus fruits and tomatoes, are not only more richly endowed than others with the antiscorbutic vitamin, but also are better able to resist destruction by drying or processing. Alkalization was shown by Hess and Unger (12) and by La Mer, Campbell, and Sherman (13) to increase the rate of loss. The influence of oxygen has been shown also to be deleterious by a number of workers, but neither acidity nor oxidation produce destructive effects which are consistent. Kohman, Eddy, and Carlsson (14), in an interesting series of experiments have shown that the exhausting of apples, spinach, and peas during commercial canning has a protective effect upon this vitamin, probably because of delayed oxidation. But a complete preliminary exhaust or removal of oxygen by respiration furnished no increase in protection of the vitamin in the case of peaches (15).

Because of these inconsistencies, and because of the economic importance of the commonly used dried fruits, this investigation into the effect of known conditions of drying upon the antiscorbutic property of certain fruits was undertaken. No previous study of commercially produced dried fruits was available with the exception of one by Eckman (16), in which peaches, prunes, apricots, apples, cherries, and berries were tested, but the results were reported without statement as to mode of drying or comparison with the corresponding fresh fruits. Negative results were obtained except in the case of the dry peaches, which were found to be partly protective. Peaches only were used in the experiments here reported, although we have data upon prunes and apricots which substantiate our conclusions, and which will be published later.
Preparation of Fruit.

The fruit was prepared by members of the staff of the Fruit Products Laboratory of the College of Agriculture of the University of California. Fresh, completely ripe peaches of the Muir variety, grown near Walnut Creek, California, were picked, pitted, ground in a food chopper, and at once packed in small tin containers, which were sealed without heating, and frozen hard. The fresh fruit was kept in a freezing room at approximately \(-17^\circ\) until it was ready to be fed. There seemed to be no change in vitamin content throughout several months storage when fresh fruit was kept under these conditions. Other portions of Muir peaches from the same trees were dried in various ways, as indicated in Table I. None of the fruit was peeled. After being

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<tr>
<td>Peaches, Muir variety.</td>
<td>Fresh.</td>
<td>Cut, pitted, ground, sealed cold in 8 oz. tin containers, frozen and kept at (-17^\circ).</td>
<td>79.57</td>
<td>1.00</td>
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<td></td>
<td>Sun-dried, unsulfured.</td>
<td>Cut, pitted, sun-dried 8 days, dried in stack 6 days.</td>
<td>19.70</td>
<td>3.93</td>
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<td></td>
<td>Sun-dried, sulfured.</td>
<td>Cut, pitted, sulfured over-night, sun-dried 8 days, dried in stack 6 days.</td>
<td>15.40</td>
<td>4.14</td>
<td>1875</td>
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<td>Dehydrated, unsulfured</td>
<td>Cut, pitted, dried in dehydrator at 63(^\circ) for 20 to 24 hrs.</td>
<td>19.12</td>
<td>3.96</td>
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<td>Dehydrated, sulfured.</td>
<td>Cut, pitted, sulfured over-night, dried in dehydrator at 63(^\circ) for 20 to 24 hrs.</td>
<td>16.01</td>
<td>4.11</td>
<td>1840</td>
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dried all peaches were ground in a food chopper, packed without heating in 8 oz. cans, and stored at approximately 
-17°.

The moisture content of all preparations was determined by 
drying at 70° in vacuo to constant weight, and sulfur dioxide was 
determined by distillation into standard iodine solution, according 
to the official method of the Association of Official Agricultural 
Chemists (17). \(^1\) These results are shown in Table I. The mois-
ture content of these products is less than that usually found in 
marketed fruit, since these figures represent dry yard fruit, which 
was not subjected to the usual steam or water processing which 
the packers carry out.

**Method of Feeding.**

The basal diet used for all the feeding tests was a slight modification of that proposed by Sherman, La Mer, and Campbell (18).

**Basal Diet; Scurvy-Producing.**

Rolled oats.................69 Cod liver oil, per day, per
Skim milk powder (baked at 110° for 2 hours)...30 animal fed separately....2 cc.
Sodium chloride..............1

On this diet, supplemented daily by 12 cc. of canned tomato 
juice, young guinea pigs grew rapidly and remained free from 
scurvy. Without the tomato or other source of vitamin C, the 
animals succumbed with severe scurvy in 25 to 35 days. All 
guinea pigs, weighing about 300 gm. at the beginning, were kept 
in separate metal cages on shavings, with fresh water and basal 
diet before them at all times. They were weighed twice a week, 
and were kept on the protective dosage of fruit for 90 days. All 
that died or that were sacrificed at the end of the test period were 
examined for signs of scurvy. Hemorrhagic areas in intestines, 
peritoneum, joints, and gums were examined, and fragility of 
bones, looseness of teeth, and beading of ribs were noted.

The test doses of fruit were given daily separately from the rest 
of the diet, and full consumption of these doses was insured. In

\(^1\) We acknowledge with thanks the assistance of Emil M. Mrak, Wong Yu 
Fong, and H. M. Reed who prepared the fruit and made the moisture and 
sulfur dioxide determinations under the supervision of Professor W. V. 
Crnuess and P. F. Nichols of the Fruit Products Laboratory.
Table II are summarized the results of the feeding tests with the peach preparations. The marked protective action of the sulfured fruit of both dehydrated and sun-dried varieties appears to indicate complete retention of the antiscorbutic property of the fresh peach. There would appear to be slightly better retention in the dehydrated than in the sun-dried product, a result which is not unexpected in view of the probably greater opportunity for oxidation in the latter case. All animals fed the unsulfured fruit, both sun-dried and dehydrated, succumbed nearly as early as did those on basal diet alone. It proved impossible to feed larger doses than 10 gm. of these products. There was little variation

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<tr>
<td>Fresh peach (Muir).</td>
<td>5 5.0 2</td>
<td>416 542 329</td>
<td>6</td>
<td>90</td>
<td>Mild scurvy.</td>
<td></td>
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<td></td>
<td>8 8.0 4</td>
<td>333 513 434</td>
<td>8</td>
<td>90</td>
<td>No &quot; &quot; &quot; &quot;</td>
<td></td>
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<tr>
<td></td>
<td>10 10.0 3</td>
<td>320 573 570</td>
<td>19</td>
<td>90</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td></td>
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<tr>
<td>Dehydrated peach, un-sulfured.</td>
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<tr>
<td></td>
<td>1 3.9 2</td>
<td>363 386 242</td>
<td>30</td>
<td>30</td>
<td>Severe scurvy, died.</td>
<td></td>
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<tr>
<td></td>
<td>2 7.9 2</td>
<td>316 346 229</td>
<td>14</td>
<td>45</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td></td>
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<tr>
<td></td>
<td>5 19.8 2</td>
<td>328 408 250</td>
<td>11</td>
<td>46</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
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<tr>
<td></td>
<td>10 39.6 2</td>
<td>367 409 217</td>
<td>30</td>
<td>32</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>Dehydrated peach, sulfurized.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>1 4.1 3</td>
<td>345 508 499</td>
<td>12</td>
<td>90</td>
<td>No scurvy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 8.2 3</td>
<td>319 484 479</td>
<td>13</td>
<td>90</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>Sun-dried peach, un-sulfured.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 3.9 2</td>
<td>306 369 224</td>
<td>14</td>
<td>42</td>
<td>Severe scurvy, died.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 7.8 2</td>
<td>319 365 216</td>
<td>21</td>
<td>38</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
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<tr>
<td></td>
<td>5 19.6 3</td>
<td>315 583 219</td>
<td>16</td>
<td>41</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
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<tr>
<td></td>
<td>10 39.3 2</td>
<td>304 404 215</td>
<td>27</td>
<td>33</td>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
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<tr>
<td>Sun-dried peach, sulfurized.</td>
<td></td>
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<tr>
<td></td>
<td>1 4.2 5</td>
<td>340 478 413</td>
<td>6</td>
<td>90</td>
<td>1 animal, mild scurvy, others, no scurvy.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 8.3 3</td>
<td>326 491 473</td>
<td>11</td>
<td>90</td>
<td>No scurvy.</td>
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Relative Antiscorbutic Value of Fresh and Dried Peach Products.
in the response of the animals to the fruit feeding, and quite uniform conditions were discovered on autopsy. The only abnormality observed in the animals fed the sulfured fruit was a slight chalkiness and brittleness of the incisors. These are now being examined chemically and microscopically.

Similar but less pronounced effects are now being obtained in tests upon prunes and apricots. The effect of lye-dipping upon the preservation of vitamin C in both sulfured and unsulfured prunes remains to be discovered, and experiments upon this, as well as upon sun-dried and dehydrated sulfured prunes, and upon apricots sulfured lightly and heavily, are now under way.

The minimum protective dose of fresh peaches, 8 gm., is slightly greater than that mentioned by Kohman, Eddy, Carlsson, and Halliday (15), but since they do not give the variety of peach used, because they used random specimens from the market, a close comparison is scarcely to be expected. It is probable that Hess and Ungcr (3) and Eckman (16) used unsulfured prunes in their negative experiments, although there is a possibility that Eckman used sulfured peaches in the experiments in which peaches showed some protective effect.

A few tests of the hydrogen ion concentration of these fruit preparations were made by Mr. H. M. Reed of the Fruit Products Laboratory. He used both electrometric and colorimetric methods, but was able to obtain satisfactory results chiefly with the hydrogen electrode. The technique of this determination is now being studied and more satisfactory figures for the pH of the later 1928 fruit samples will undoubtedly be available. The sun-dried sulfured peaches gave 4.2 as compared with the usual 4.0 to 4.4 of fresh peaches. There would appear from these limited observations to be no necessary relation between the sulfuring and the pH of these fruits.

The mechanism of protection of vitamin C by the sulfur dioxide treatment in these fruits is of interest and is being studied in this laboratory. Whether the result is due to decreased oxidation because of a surface coagulation of the fruits, or because of the reducing action of the sulfur dioxide, or to greater stability of the vitamin in the possibly more acid medium provided by the sulfurous acid, or to some other cause remains to be discovered. In any case, a definite advantage in an important phase of dried
fruit nutritive value, appears to be derived from the sulfur dioxide treatment during drying.

In view of the long disputed question as to the possibly deleterious effects of sulfurous acid in dried fruits, these findings are somewhat surprising. Food Inspection Decision No. 76 of the United States Department of Agriculture which is widely quoted in textbooks, states that the total amount of sulfur dioxide in the finished product must not exceed 350 mg. per kilo. This decision is not enforced because of the confusion of opinions and the lack of convincing data as to the actual effects of sulfuring upon the economic and physiological aspects of the use of such dried fruit. Much of the sulfured dried fruit marketed in this country carries more than 1000 parts of sulfur dioxide per million. Certain European states, France, for instance, have recently begun to enforce a minimum of 1000 parts per million. In Hungary, Germany, and Czecho-Slovakia, 1250 parts per million, in England 2000, and in Canada 2500 parts per million are the legal minima. New York has named 2000 parts per million as minimum, and New Hampshire has recently prohibited sulfur dioxide in any amount whatever. Most of the states, however, have accepted the federal ruling indicated in Food Inspection Decision 89, issued in 1908, that "ordinary" quantities of sulfur dioxide if stated on the label are not objectionable. The objection to excessive sulfuring appears now to be rather on the score of the possible marketing of excessively watery dried fruits rather than based on the danger of physiological injury resulting from their ingestion.

It seems desirable therefore to know at what level of sulfur dioxide content the protective action upon vitamin C is effective, in order that legal minima, if these are to be established, may be made most advantageous in the nutritive sense. Further experiments upon prunes and apricots with widely varying sulfur dioxide content have therefore already been undertaken in this laboratory.

The antiscorbutic vitamin content of the sulfured dried peaches used in this study is as high as that of any other foods yet reported, 1 gm. daily being sufficient to protect standard guinea pigs from scurvy over a period of at least 90 days. For similar protection there are required 1.5 to 3 gm. of oranges or lemon juice, or fresh tomato, 3 times as much banana, 6 times as much raw apple or pear or cooked potato, and nearly twice as much pineapple.
SO₂ and Antiscorbutic Effect

SUMMARY.

1. Peaches of known origin, namely, fresh, sun-dried, and dehydrated, both sulfured and unsulfured, were tested for vitamin C content.

2. The sulfured peach products retained the full antiscorbutic vitamin content of the fresh fruit, but the unsulfured sun-dried and dehydrated peaches retained no detectable amount of this property. The suggested possible relation of vitamin C protection to a minimum sulfur dioxide content or acidity is now under investigation.

3. The sulfured dried peach preparations were found to rank with orange juice, raw tomatoes, and other highly potent antiscorbutic foods.

BIBLIOGRAPHY.

CORRECTIONS.

On page 585, Vol. lxxxii, No. 3, June, 1929, lines 15 and 18, read *maximum* for *minimum*; lines 17 and 29 read *maxima* for *minima*.

On page 778, Vol. lxxxii, No. 3, June, 1929, line 5, read

\[ pH_{38^o} = \frac{E.M.F. - e}{0.06169} \quad \text{for} \quad pH_{38^o} = \frac{E.M.F. \cdot e}{0.06169} \]

On page 110, Vol. lxxxiii, No. 1, July, 1929, line 6 from the foot of the page, read, *Sodium tungstate does, sodium molybdate does not, for Sodium molybdate does, sodium tungstate does not.*
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