VITAMINS IN DRIED FRUITS.

II. THE EFFECT OF DRYING AND OF SULFUR DIOXIDE UPON THE VITAMIN A CONTENT OF FRUITS.*

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Some of the early studies on the vitamin content of dried fruits and vegetables are open to the objection that the products studied either were not commercial or were dried under conditions that affect adversely many qualities other than vitamins of the products. This report covers a part of an investigation undertaken cooperatively by the two laboratories involved, and intended to show the effect on vitamins of some of the treatments ordinarily employed in successful drying. The inquiry has developed largely into a study of the conditions under which vitamins A and C are protected or destroyed. We have already reported the remarkably protective effect of sulfur dioxide (1) upon the vitamin C of dried peaches, and have continued the study of this factor in prunes, apricots, and figs. Sun drying with its long continued slow oxidations as compared with the relatively rapid dehydration process at higher temperatures might be expected to bring about a different rate of loss or retention in those vitamins, particularly A and C, which have been shown to be readily destroyed by oxidation. The protective effect of sulfur dioxide upon the vitamin C of peaches may be due either to the acid reaction thus induced or more probably to the reducing character of the sulfites formed. In either case a similar protection of vitamin A might be expected to be manifest in the same fruits. Evidence on this point is presented herein.

A recent publication by Cady and Luck (2) describes rather

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drastic treatment with sulfur dioxide of cod liver oil, butter fat, and alfalfa, with subsequent testing of these materials for vitamin A. Cod liver oil was found to have lost most of its vitamin A after treatment with sulfur dioxide for 15 minutes to 2 hours at 20–100°, but butter fat treated with the gas at 60° for 2 hours had lost but little, and alfalfa or spinach alcohol extracts treated with sulfur dioxide for 1 hour at 60° had apparently suffered no loss of vitamin A. The treated foods were incorporated in the basal diet, so that intake of the vitamin-containing materials was irregular. The difference between the effects upon cod liver oil and the other foods might well be due to autooxidation of the vitamin induced by the catalytic action of some constituent of the basal diet in the fashion observed by McCollum, Simmonds, and Becker (3) as due to ferrous sulfate, and by Mattill (4). Such catalysis might be conceived of as possible only in the presence of any sulfite compound formed by the sulfur dioxide treatment. Feeding of the foods to be tested in separate doses should obviate this uncertainty to some extent.

Since, as Anderegg and Nelson (5) have shown, water and ethyl alcohol tend to decrease the rate of autooxidation and unsaturated fatty acids to increase it, both butter and alcoholic extracts of alfalfa would be more resistant to such action than cod liver oil. It seems unnecessary, therefore, to postulate a difference in nature of the vitamin A of cod liver oil from that in butter and alfalfa to explain the observed difference in effect of sulfur dioxide when such striking oxidative differences have been shown to be due to the catalytic action of accompanying substances present in perhaps minute amount in the basal ration. The varying results obtained by Dulièrè, Morton, and Drummond (6), by von Euler, von Euler, and Karrer (7), Moore (8), and Hume and Smedley-Maclean (9) on the vitamin A activity of purified carotene crystals may be due to similar variations in the oxidative action of the fatty carriers of the carotene. The differences seen by Sherman, Quinn, Day, and Miller (10) between the amount of destruction of vitamin A in olive oil extracts of butter fat and of spinach when heated under anaerobic conditions may also be ascribed to possible differences in catalysts present rather than to differences in stability of the vitamin.

The vitamin A content of preserved food samples is no doubt de-
termi
nded partly by the catalytic effect of other substances natu-
dr
rally present in the foods as well as by the vitamin value of the
d
fresh specimen. It is probably useless to expect, then, that similar
preserving processes will yield products of like vitamin A retention
from foods of different composition. As will be shown later, exam-
pl
les of such divergences were found among the fruits here reported
upon.

Preparation and Chemical Examination of Fruit.\textsuperscript{1}—All fruit
samples, both fresh and dried, were gathered, dried, sealed, an-
alyzed, and stored under the supervision of W. V. Cruess and P.
F. Nichols of the Fruit Products Laboratory. Dried fruit samples
were stored at 0°.

The peaches used were of the 1927 crop, Muir variety, grown
near Walnut Creek, California, and were prepared by sulfuring,
dehydration, or sun drying as previously described (1). The
fresh fruit was ground and frozen. The prunes were of the 1928
crop, French variety, and were grown near Edenvale, California.
The lye-dipped prunes were immersed for about 5 seconds in a
practically boiling 0.5 per cent lye solution, followed by spraying
with fresh water. The apricots, also of the 1928 crop, were of the
royal variety and were grown near Watsonville, California. All
dehydrated fruit samples were dried in a tunnel drier at tempera-
tures increasing from about 49–71° as drying progressed, relative
humidity similarly decreasing from 70 to 20 per cent, and with a
constant air velocity of approximately 500 feet per minute. The
time required for dehydration varied with the different fruits,
ranging from 20 to 30 hours as shown in Table I.

The moisture content of the fresh fruit and of the dried peaches
and apricots was determined by oven drying \textit{in vacuo} at 70° for
12 hours, and of the dried prunes by the xylene distillation method.
To allow for the presence of pits in the dried prunes an arbitrary
adjustment of 1 per cent additional moisture was made.

The sulfur dioxide content of all dried samples was found by dis-
tillation with HCl into iodine, a modification of the official method
of the Association of Official Agricultural Chemists (11).

\textsuperscript{1} The preparation and analysis of the samples were carried out by W. Y.
Fong, P. F. Nichols, and H. M. Reed of the Fruit Products Laboratory, except that the moisture and sulfur dioxide determinations upon the dried prunes were made by R. S. Hiltner and B. E. Hatherell of the Dried Fruit Association of California. We are indebted to this Association also for the fruit and for other support of this investigation.
TABLE I.
Preparation and Composition of Fruit.

<table>
<thead>
<tr>
<th>Fruit.</th>
<th>Lot.</th>
<th>Method of preparation.</th>
<th>Moisture, per cent</th>
<th>Nit. shrinkage</th>
<th>pH</th>
<th>Sulfur dioxide, parts per million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muir peaches, 1927 crop.</td>
<td>F</td>
<td>Cut, pitted, ground, sealed cold in 8 oz. tin containers, frozen and kept at -17°.</td>
<td>79.5</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Cut, pitted, sun-dried 8 days, dried in stack 6 days.</td>
<td>19.7</td>
<td>3.93</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>Cut, pitted, sulfured overnight, sun-dried 8 days, dried in stack 6 days.</td>
<td>15.4</td>
<td>4.14</td>
<td>3.6</td>
<td>1875</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Cut, pitted, dried in dehydrator at 63° for 20 to 24 hrs.</td>
<td>19.1</td>
<td>3.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SE</td>
<td>Cut, pitted, sulfured overnight, dried in dehydrator at 63° for 20 to 24 hrs.</td>
<td>16.0</td>
<td>4.11</td>
<td></td>
<td>1840</td>
</tr>
<tr>
<td>Elberta peaches, 1928 crop.</td>
<td>LS</td>
<td>Cut, pitted, ground, placed in small glass jars, evacuated, filled with carbon dioxide, frozen, and kept at -17°.</td>
<td>85.8</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>French prunes, 1928 crop.</td>
<td>10</td>
<td>Cut, pitted, ground, sealed cold in 8 oz. tin containers, frozen and kept at -17°.</td>
<td>62.6</td>
<td>1.00</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Dehydrated whole for 30 hrs. at 72° average temperature for 30 hrs. after lye dipping, washing, and sulfuring overnight.</td>
<td>19.0</td>
<td>2.17</td>
<td>3.2</td>
<td>1980</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Same as for 11, but without sulfuring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Same as for 11, but without lye dipping.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Same as 13, but sun-dried for 7 days, held in stack for 7 days, instead of being dehydrated.</td>
<td>19.8</td>
<td>2.15</td>
<td>3.1</td>
<td>1005</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>Dehydrated whole for 30 hrs., without previous lye dipping or sulfuring.</td>
<td>21.4</td>
<td>2.10</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Fruit</td>
<td>Lot</td>
<td>Method of preparation</td>
<td>Moisture</td>
<td>Net shrinkage</td>
<td>pH</td>
<td>Sulfur dioxide</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------</td>
<td>----------------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>---------------</td>
<td>--------</td>
<td>----------------</td>
</tr>
<tr>
<td>French prunes, 1928</td>
<td>16</td>
<td>Sun-dried 7 days, kept in stack 7 days, without previous lye dipping or sulfuring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>Lye-dipped, washed, sulfured overnight, sun-dried 7 days, held in stack 7 days.</td>
<td>20.2</td>
<td>2.13</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>Same as 17 except that sulfuring was omitted.</td>
<td>17.8</td>
<td>2.20</td>
<td>2.6</td>
<td>2695</td>
</tr>
<tr>
<td>Royal apricots, 1928</td>
<td>5</td>
<td>Pitted, ground, sealed cold in 8 oz. tin containers, frozen, and kept at −17°.</td>
<td>82.9</td>
<td>1.00</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>Another fresh sample. Pitted, ground, placed in small glass jars, evacuated, filled with</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>carbon dioxide, frozen, and kept at −17°.</td>
<td>82.0</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Cut, pitted, sulfured 3½ hrs., dehydrated 2 hrs. at 72° average temperature.</td>
<td>18.8</td>
<td>4.75</td>
<td>2.4</td>
<td>515</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Cut, pitted, sulfured 30 min., dehydrated 24 hrs. at 72° average temperature.</td>
<td>17.0</td>
<td>4.85</td>
<td>2.9</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Cut, pitted, dehydrated 24 hrs. at 72° average temperature.</td>
<td>22.6</td>
<td>4.53</td>
<td>3.2</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Cut, pitted, steamed 3½ min., sulfured 20 min., dehydrated 24 hrs. at 72° average</td>
<td>16.3</td>
<td>4.89</td>
<td>3.2</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Cut, pitted, sulfured 2½ hrs., sun-dried 11 days.</td>
<td>19.0</td>
<td>4.73</td>
<td>3.3</td>
<td>700</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Same as 6, but sulfured only 30 min.</td>
<td>17.5</td>
<td>4.82</td>
<td>3.1</td>
<td>470</td>
</tr>
</tbody>
</table>

The pH of fresh and rehydrated dry samples was determined by the hydrogen electrode upon the pulp. As may be noted in Table I, sulfuring usually, but not invariably, decreased the pH of the fruit.
Vitamin A in Dried Fruits

Certain vitamin A values for 1928 Elberta peaches and royal apricots obtained by Laura Lee W. Smith in this laboratory upon samples grown at Davis, California, are included among our results for purposes of comparison. These samples were both of the fresh frozen type and differed from the others reported in that they were sealed in small jars, prepared by evacuation and release with carbon dioxide before being frozen in order to decrease the danger of oxidation.

Methods of Testing for Vitamin A.—The methods of testing for vitamin A used in this study were not markedly different from those which have now become usual for quantitative comparisons of vitamin content of foods. Rats from our own colony, reared by mothers fed a constant stock diet which had been used for several generations of animals, were placed at 21 days of age upon a vitamin A-free basal diet. This diet consisted of baked and alcohol-extracted casein 18 parts, irradiated Crisco 5, agar 2, salt mixture\(^2\) 4, dextrin 71. In addition, 0.5 gm. of dried yeast was given separately to each rat daily. The fruit doses were weighed out accurately, made into pellets with a little of the basal ration and fed separately. In most cases the fruit was fed in three or four doses per week, although in a few cases the entire amount for the 56 days was given in one or two doses at the beginning of the period. The latter procedure was found to be undesirable, however, and to give less favorable findings than the usual daily or tri-weekly feeding.

The feeding of curative fruit doses was begun only after the usual signs of vitamin A deficiency had become evident. The period required for the production of these symptoms varied from 25 to 35 days. Ophthalmia occurred in practically all cases. The fruit feeding period was 56 days in length, and an attempt was made to obtain graded growth response to graded dosage. The standard unit chosen was that amount of fruit which produced an average weekly increase of weight of 6 to 8 gm. for the 8 weeks of observation. This rate of growth was chosen rather than the 3 gm. weekly advocated by Sherman and Munsell (12) because rats maintained at the latter rate are apt to be seriously affected by intercurrent and accidental results of their extremely low vitamin A margin.

Postmortem examinations of all animals were made, particularly as to the condition of the stomach, kidneys, throat, and ears.

### TABLE II.

**Vitamin A in Fresh and Dried Peaches.**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Lot.</th>
<th>Amount given daily</th>
<th>Equivalent in fresh fruit</th>
<th>Average weights</th>
<th>Average gain per wk. for 8 wks.</th>
<th>No. of rats used</th>
<th>Minimum dose equivalent in fresh fruit allowing growth per wk.</th>
<th>Vitamin A retention in product.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Muir peaches, 1927 crop.</td>
<td>F</td>
<td>100 100</td>
<td>47 88</td>
<td>5.1</td>
<td>4</td>
<td>160</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Unsulfured, dehydrated Muir peaches.</td>
<td>E</td>
<td>34135 104</td>
<td>95 -1.0</td>
<td>2</td>
<td>1 ophthalmic.</td>
<td>178</td>
<td>About 50.</td>
<td></td>
</tr>
<tr>
<td>Unsulfured, sun-dried Muir peaches.</td>
<td>D</td>
<td>34133 105</td>
<td>151 5.7</td>
<td>2</td>
<td>1 ophthalmic.</td>
<td>177</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Sulfured, dehydrated Muir peaches.</td>
<td>SE</td>
<td>34140 110</td>
<td>167 7.1</td>
<td>2</td>
<td>1 ophthalmic.</td>
<td>140</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Sulfured, sun-dried Muir peaches.</td>
<td>SD</td>
<td>34141 156</td>
<td>139 -2.0</td>
<td>1</td>
<td>1 ophthalmic.</td>
<td>186</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>Fresh Elberta peaches, 1928 crop.</td>
<td>LS</td>
<td>50 50</td>
<td>40 76</td>
<td>4.5</td>
<td>4</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Abscesses in throat and ears were commonly found in the rats which had died of the deficiency. Abnormalities in the kidneys
### TABLE III.
**Vitamin A in Fresh and Dried Prunes.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
</tr>
<tr>
<td>10</td>
<td>150</td>
<td>4</td>
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<td>12</td>
<td>13</td>
<td>14</td>
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<tr>
<td>150</td>
<td>200</td>
<td>2</td>
<td></td>
<td>75</td>
<td>75</td>
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<td>250</td>
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<td>2</td>
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<td>100</td>
<td>3</td>
<td>12</td>
<td>50</td>
<td>100</td>
<td>108</td>
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<tr>
<td>87</td>
<td>109</td>
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<td>12</td>
<td>110</td>
<td>110</td>
<td>107</td>
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<td>75</td>
<td>136</td>
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<td>1</td>
<td>120</td>
<td>120</td>
<td>105</td>
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<td>220</td>
<td>3</td>
<td>1</td>
<td>110</td>
<td>110</td>
<td>102</td>
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<td>240</td>
<td>240</td>
<td>4</td>
<td>2</td>
<td>220</td>
<td>220</td>
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<td>3</td>
<td>1</td>
<td>143</td>
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<td>86</td>
<td>138</td>
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<td>1</td>
<td>143</td>
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<td>240</td>
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<td>4</td>
<td>2</td>
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<td>109</td>
<td>117</td>
<td>3</td>
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<td>340</td>
<td>4</td>
<td>2</td>
<td>240</td>
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<td>240</td>
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</table>

**Average weights:**

<table>
<thead>
<tr>
<th>Initial</th>
<th>Final</th>
<th>Average gain per wk.</th>
<th>Minimum daily dose</th>
<th>Retention of vitamin A of fresh fruit.</th>
</tr>
</thead>
<tbody>
<tr>
<td>gm.</td>
<td>gm.</td>
<td>gm.</td>
<td>gm.</td>
<td>per cent</td>
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<td>76</td>
<td>153</td>
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<td>169</td>
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<td>6.1</td>
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<td>149</td>
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<td></td>
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<tr>
<td>91</td>
<td>172</td>
<td>2.7</td>
<td>420</td>
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<tr>
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<td>7.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>105</td>
<td>3.4</td>
<td>232</td>
<td>43</td>
</tr>
<tr>
<td>71</td>
<td>104</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>149</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>138</td>
<td>7.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>93</td>
<td>151</td>
<td>7.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
and crater-like tumors in the stomachs were also present in the vitamin A-low cases and occasionally even in those which had apparently resumed nearly normal growth. The persistence of slight ophthalmias was seen likewise in a few cases which had otherwise all indications of vitamin A normality.

The method of estimating per cent retention of vitamin A used in Tables II to IV, is somewhat arbitrary, since it is based upon the assumption that average increases in body weight are correlated with similar vitamin A intakes. The dose of the frozen fresh fruit which permits at least 6 gm. gain per week for 8 weeks is taken as the vitamin A unit and is considered to represent 100 per cent of the vitamin A content of this fruit. The dose of the dried fruit product, calculated as its fresh fruit equivalent, which allows a similar gain in weight is looked upon as containing a similar amount of vitamin A, and the ratio between the weight of the frozen fresh fruit dose and that of the dried product equivalent in fresh weight is taken as the ratio of loss of vitamin A. The resulting percentages are only roughly indicative of the changes which have occurred and are reliable only when consistently graded growth has been obtained from graded doses of the fruit.

### Table II—Concluded.

<table>
<thead>
<tr>
<th>Lot No.</th>
<th>Equivalent in fresh fruit.</th>
<th>Condition of eyes.</th>
<th>Average gain per wk.</th>
<th>Retention of vitamin A of fresh fruit.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg.</td>
<td>mg.</td>
<td>g.m.</td>
<td>g.m.</td>
</tr>
<tr>
<td>Lye-dipped, sulfured, sun-dried.</td>
<td>17</td>
<td>50</td>
<td>110</td>
<td>4</td>
</tr>
<tr>
<td>Lye-dipped, unsulfured, sun-dried.</td>
<td>18</td>
<td>50</td>
<td>111</td>
<td>4</td>
</tr>
<tr>
<td>Normal.</td>
<td>75</td>
<td>165</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Normal.</td>
<td>100</td>
<td>225</td>
<td>1</td>
<td>Normal.</td>
</tr>
</tbody>
</table>

The method of estimating per cent retention of vitamin A used in Tables II to IV, is somewhat arbitrary, since it is based upon the assumption that average increases in body weight are correlated with similar vitamin A intakes. The dose of the frozen fresh fruit which permits at least 6 gm. gain per week for 8 weeks is taken as the vitamin A unit and is considered to represent 100 per cent of the vitamin A content of this fruit. The dose of the dried fruit product, calculated as its fresh fruit equivalent, which allows a similar gain in weight is looked upon as containing a similar amount of vitamin A, and the ratio between the weight of the frozen fresh fruit dose and that of the dried product equivalent in fresh weight is taken as the ratio of loss of vitamin A. The resulting percentages are only roughly indicative of the changes which have occurred and are reliable only when consistently graded growth has been obtained from graded doses of the fruit.
### Vitamin A in Fresh and Dried Apricots

<table>
<thead>
<tr>
<th>Royal apricot, 1938</th>
<th>Lot No.</th>
<th>Amount fed daily, mg.</th>
<th>Equivalent in fresh fruit</th>
<th>No. of rats used</th>
<th>Condition of eyes</th>
<th>Average weights, gm.</th>
<th>Minimum daily dose for growth, gm. per wk.</th>
<th>Retention of vitamin A of fresh fruit. per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>25</td>
<td>1</td>
<td>3</td>
<td>Normal</td>
<td>92</td>
<td>151</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>50</td>
<td>1</td>
<td>5</td>
<td>&quot;</td>
<td>66</td>
<td>144</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>4</td>
<td></td>
<td>&quot;</td>
<td>60</td>
<td>131</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>150</td>
<td>3</td>
<td></td>
<td>&quot;</td>
<td>68</td>
<td>149</td>
<td>10.2</td>
</tr>
<tr>
<td>Sulfured, dehydrated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>1 ophthalmic</td>
<td>53</td>
<td>75</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>95</td>
<td>4</td>
<td></td>
<td>Normal</td>
<td>58</td>
<td>110</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>143</td>
<td>2</td>
<td></td>
<td>&quot;</td>
<td>51</td>
<td>111</td>
<td>7.5</td>
</tr>
<tr>
<td>Sulfured, dehydrated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1 ophthalmic</td>
<td>73</td>
<td>99</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>49</td>
<td>4</td>
<td></td>
<td>Normal</td>
<td>63</td>
<td>113</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>97</td>
<td>3</td>
<td></td>
<td>&quot;</td>
<td>60</td>
<td>117</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>146</td>
<td>2</td>
<td></td>
<td>&quot;</td>
<td>70</td>
<td>128</td>
<td>7.2</td>
</tr>
<tr>
<td>Unsulfured, dehydrated.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>10</td>
<td>2</td>
<td>1</td>
<td>1 ophthalmic</td>
<td>68</td>
<td>101</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>90</td>
<td>4</td>
<td></td>
<td>Normal</td>
<td>65</td>
<td>97</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>135</td>
<td>5</td>
<td></td>
<td>2 ophthalmic</td>
<td>86</td>
<td>127</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>157</td>
<td>4</td>
<td>1</td>
<td>&quot;</td>
<td>89</td>
<td>159</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>170</td>
<td>2</td>
<td>1</td>
<td>1 ophthalmic</td>
<td>72</td>
<td>149</td>
<td>9.6</td>
</tr>
<tr>
<td>Sulfured, dehydrated, steamed 3½ min.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>Normal</td>
<td>68</td>
<td>118</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>98</td>
<td>9</td>
<td></td>
<td>&quot;</td>
<td>71</td>
<td>110</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>123</td>
<td>3</td>
<td></td>
<td>&quot;</td>
<td>86</td>
<td>139</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>147</td>
<td>3</td>
<td>1</td>
<td>ophthalmic</td>
<td>73</td>
<td>140</td>
<td>8.3</td>
</tr>
<tr>
<td>Sulfured, sun-dried.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>1 ophthalmic</td>
<td>81</td>
<td>99</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>95</td>
<td>4</td>
<td></td>
<td>Normal</td>
<td>62</td>
<td>106</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>118</td>
<td>4</td>
<td>1</td>
<td>ophthalmic</td>
<td>87</td>
<td>151</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>142</td>
<td>2</td>
<td></td>
<td>Normal</td>
<td>58</td>
<td>117</td>
<td>7.3</td>
</tr>
<tr>
<td>Sulfured, sun-dried.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>1</td>
<td>Normal</td>
<td>82</td>
<td>80</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>96</td>
<td>4</td>
<td>1</td>
<td>ophthalmic</td>
<td>76</td>
<td>111</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>144</td>
<td>5</td>
<td></td>
<td>Normal</td>
<td>79</td>
<td>130</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>192</td>
<td>2</td>
<td></td>
<td>&quot;</td>
<td>68</td>
<td>153</td>
<td>10.6</td>
</tr>
<tr>
<td>Fresh (another sample)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial</td>
<td>Final</td>
<td>Average gain per wk.</td>
</tr>
<tr>
<td></td>
<td>LS</td>
<td>50</td>
<td>4</td>
<td></td>
<td>Normal</td>
<td>52</td>
<td>119</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>4</td>
<td></td>
<td>&quot;</td>
<td>82</td>
<td>164</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>200</td>
<td>3</td>
<td></td>
<td>&quot;</td>
<td>79</td>
<td>181</td>
<td>12.8</td>
</tr>
</tbody>
</table>
DISCUSSION.

Peaches.—The sulfured peach products, as shown in Table II, both dehydrated and sun-dried, appeared to contain almost the whole, 86 to 100 per cent, of the vitamin A present in the corresponding fresh fruit. The unsulfured sun-dried fruit likewise retained about 90 per cent of the vitamin, but the unsulfured dehydrated product appeared to have lost nearly 50 per cent. This latter figure is only approximate since a large enough dose was not given to obtain the standard minimum weight increase of 6 gm. per rat per week. The same relation was observed in the corresponding prune preparations. Of course, the higher temperatures used in dehydration may in the absence of the protecting sulfur dioxide have proved more destructive than the sun drying temperatures.

There is apparently little danger of loss of the vitamin A of yellow peaches by either sun drying or dehydration, just as there is little loss of vitamin C in the sulfured peaches (1). The reason for this immunity to the usual loss from oxidation may reside in a low oxidase content of the fruit or in the absence of other auto-oxidative catalysts.

It is interesting to note the correspondence between the amount of yellow pigment and of vitamin A present in the fresh peaches. The Muir peaches (Lot F') were a rather pale yellow in color as compared with the deep orange-yellow of the Elberta peaches (Lot LS), and the vitamin A content of the latter as found by Laura Lee W. Smith in this laboratory is definitely greater. White peaches preserved and tested similarly were found to be almost wholly lacking in the vitamin. These findings are in line with the recent claims of von Euler, von Euler, and Karrer (7) and of Moore (8) that purified carotene is effective in minute quantities as a source of vitamin A.

Prunes.—It is clear that sulfur dioxide is of some value in preserving the vitamin A of prunes, for the two sulfured varieties in the dehydrated (Lots 11, 13) and in the sun-dried (Lots 14, 17) products show higher retentions than do the unsulfured fruit. These results are shown in Table III. But of even more importance is the choice of dehydration instead of sun drying if sulfuring is used, since both dehydrated sulfured products retain 91 per
cent of the vitamin A as compared with 60 and 62 per cent retained by the sun-dried sulfured fruit. However, again as in the peaches, when sulfuring is not used, sun drying leaves more vitamin A in the fruit, 57 and 45 per cent, than does dehydration, 41 and 24 per cent.

The effect of the lye dipping of prunes, which is the common commercial practice, upon vitamin A retention is not marked, although the dipped unsulfured prunes appear to have a higher content of the vitamin than do the corresponding undipped products. This is not the same as was found with regard to vitamin C retention, for the undipped sulfured prunes were found to have lost more of their original antiscorbutic property than did the lye-dipped sulfured fruit. Since all unsulfured fruit was without vitamin C value, the effect of the dipping in those cases was indiscernible. Apparently the lye dipping promoted vitamin C retention, through its effect upon the sulfuring, since the cracked surface of the dipped fruit absorbed more sulfur dioxide than did that of the undipped fruit. This is evident from a comparison of the figures for sulfur dioxide in the four sulfured products, Lots 11, 13, 14, and 17. The dipped prunes, Lots 11 and 17, show 2 to 3 times as much sulfur dioxide as do the corresponding undipped prunes, Lots 13 and 14. But the order of vitamin A retention is Lots 11, 13, 14, and 17, instead of Lots 17, 11, 13, and 14, as it should be if sulfur dioxide retention alone governed the vitamin A protection in the same fashion that it governs vitamin C protection.

As shown in Table V, sulfured dehydrated prunes have almost all of the vitamin A of the fresh fruit, sun-dried sulfured prunes about 60 per cent, and unsulfured prunes both dehydrated and sun-dried, 45 to 24 per cent.

The pH of the prune and apricot samples varied surprisingly little, the sulfured samples showing, as might be expected, slightly lower figures, and Lots 17 and 1, which were most highly sulfured, the lowest of all.

Apricots.—As shown in Table IV, an astonishingly large amount of the vitamin is present in fresh apricots and in all dried apricots, even though a large loss of vitamin A occurs in the dried products.

1 Results to be published later.
Again the sulfured products seem to retain more than do the unsulfured, but the actual amount of sulfur dioxide present in the fruit appears not to be the governing factor. The unusual content of vitamin A in apricots is of interest in connection with the excellent hemoglobin regeneration produced by this fruit, as observed by Robscheit-Robbins and Whipple (13).

TABLE V.
Summary of Vitamin A in Dried Fruits.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Peaches</td>
<td>SE</td>
<td>Dehydrated.</td>
<td>1840 parts/million</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Sun-dried.</td>
<td>1875</td>
<td></td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>&quot;</td>
<td></td>
<td></td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Dehydrated. Unsulfured.</td>
<td></td>
<td></td>
<td>50 (about).</td>
</tr>
<tr>
<td>Prunes</td>
<td>11</td>
<td>Dehydrated.</td>
<td>1980</td>
<td>Dipped.</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>&quot;</td>
<td>1020</td>
<td>Not dipped.</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Sun-dried.</td>
<td>1005</td>
<td>&quot;</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>&quot;</td>
<td>2695</td>
<td>Dipped.</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>&quot;</td>
<td>Unsulfured.</td>
<td>&quot;</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>&quot;</td>
<td></td>
<td>Not dipped.</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Dehydrated.</td>
<td>&quot;</td>
<td>Dipped.</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>&quot;</td>
<td></td>
<td>Not dipped.</td>
<td>24</td>
</tr>
<tr>
<td>Apricots</td>
<td>2</td>
<td>Dehydrated.</td>
<td>125</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>&quot;</td>
<td>515</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>&quot;</td>
<td>80</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Sun-dried.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Dehydrated (steamed).</td>
<td>100</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;</td>
<td>(unsulfured).</td>
<td></td>
<td>16</td>
</tr>
</tbody>
</table>

The quantities of sulfur dioxide found in the apricot samples were lower than were expected, particularly in the samples which were thought to be heavily sulfured. None of the apricots was sulfured overnight as were the peaches and prunes, and consequently less sulfur dioxide was retained by the former fruit. Sulfuring periods of 20 minutes to 31/2 hours are long enough to produce satisfactorily bleached apricots but apparently not long enough to insure complete protection of vitamin A. Similar results were
Vitamin A in Dried Fruits

encountered in the tests for vitamin C in this fruit. The discrepancy between the retention of vitamin A in Lots 1 and 2 is surprising since amount of sulfuring and pH of the former product would lead one to expect it to be superior instead of inferior to the latter. The difference may not be significant, however.

Sun drying involves greater loss than does dehydration when the sulfuring process is used. Since the one unsulfured apricot product, Lot 3, happened to be dehydrated, it is impossible to say whether the curious exception to the superiority of dehydration in unsulfured fruit noted in the peaches and prunes is true of apricots as well.

The losses of 49 to 84 per cent of the vitamin in the drying of apricots may well be connected with the unusual air retention seen in the frozen fresh fruit. As will be shown in a later report, the fresh frozen apricots lost much of their antiscorbutic property when frozen without previous evacuation and at the same time on thawing gave off a considerable amount of gas, apparently largely air. Similar losses were not encountered in the frozen fruit used for vitamin A determination even when compared with the results of determinations upon royal apricots, Lot LS, frozen after evacuation. This might be taken to indicate less susceptibility to autooxidation by the vitamin A than the vitamin C, or perhaps the presence in this fruit of catalysts peculiarly active in regard to the latter vitamin.

The possible rôle of the ultra-violet portion of sunlight in promoting oxidations of both vitamins A and C must be considered in evaluating the effects of sun drying. The antioxidative effect of the sulfur dioxide appears to function under these circumstances, however, since the sun-dried products were richer in vitamin A than were the dehydrated ones without sulfur, but the opposite was true when sulfur was used.

Effect of Storage.—After 12 to 14 months storage at 0° several of the dried prune and apricot products were retested in order to fill in the series of graded dosages. The products thus examined were Lots 12, 15, 16, and 18 of the prunes and 3 and 4 of the apricots. As may be seen in Tables III and IV, the results fell into line quite acceptably with the results recorded at least a year previously upon the same samples. The prune doses used in the second series were 110 mg. of Lot 12, 200 mg. of Lot 15, 110 and
A. F. Morgan and A. Field

120 mg. of Lot 16, and 80 and 85 mg. of Lot 18. The apricot doses were 35 mg. of Lot 3 and 25 mg. of Lot 4. It is fair to assume probably that no losses of vitamin A are likely to occur on long storage of these dried fruits at 0°.

The actual quantity of vitamin A in the frozen fresh apricots is surprisingly large. Results obtained by the same methods (14) in this laboratory appear to show that the apricots are 4 or 5 times as active as tomatoes and to compare favorably with such rich sources of the vitamin as egg yolk, butter, and spinach (15), even when the values of the latter are expressed in terms of the smaller unit, 3 gm. growth per rat per week, used by Sherman and Munsell (12). In consequence, even the least successful of the drying processes left a good proportion of vitamin A in the apricot products.

The yellow peaches are about one-fourth as rich in vitamin A as are the apricots and in the case of the Elberta variety appear to be almost identical in value with tomatoes. The paler Muir peach has about two-thirds the vitamin A value of the Elberta. The dried peach products on the other hand proved to be almost as rich in the vitamin as the dried apricots because of their almost perfect protection of the vitamin during the drying processes.

The prunes, contrary to our earlier expectations, appeared to be fully equal to the Elberta peaches in vitamin A value. Tests upon this fruit are being made to discover the carotenoid content of the pulp in pursuance of the question as to the identity of carotene and vitamin A.

Compared with tomatoes (14) tested by the same criteria, and bananas (16) and lettuce (17) by the less severe standards of Sherman and Munsell, both Elberta and Muir peaches and French prunes are considerably the richer sources of vitamin A.

It is interesting to note that the conditions which have been found to favor retention of both vitamins A and C in dried fruit products are just those which popular prejudice and even official regulation have heretofore frowned upon. Indeed, there are to be found among so called "health foods" now on the market, high priced special preparations of sun-dried and unsulfured fruits. The sulfured dehydrated fruits on the other hand, have here been found without exception to be superior in vitamin retention.
SUMMARY.

1. The vitamin A content of frozen fresh and variously dried samples of peaches, prunes, and apricots was determined by uniform biological technique.

2. *The sulfured dehydrated* fruit in all cases appeared to retain the largest proportion of the vitamin, but this retention was not found to be directly related to the amount of sulfur dioxide in the fruit.

3. Of the *unsulfured* fruit, the *sun-dried* specimens of prunes and peaches showed better retention of vitamin A than did the corresponding *unsulfured dehydrated* products. The more destructive effect, in the absence of the protective sulfur dioxide, of the higher temperatures used in dehydration is the only explanation of this divergence offered.

4. *Lye dipping* of the dried prunes seemed to exert no effect upon vitamin A retention.

5. The amount of destruction of vitamin A produced by comparable methods of preservation varies widely in the three fruits.

   The vitamin A of *peaches* seems little affected by any of the drying processes, 86 to 100 per cent being retained in all cases. The vitamin A of *prunes* is more labile, 24 to 91 per cent being retained, and that of *apricots* still more easily affected, only 16 to 51 per cent of the fresh fruit value being present in the dried preparations. However, the dried apricots which had lost the greatest proportions of their fresh fruit vitamin A content were still absolutely richer in this vitamin than the best of the peach and prune products. Differences in amounts and kinds of oxidative catalysts present in the fruits are thought to account for these variations.

6. Storage of both sulfured and unsulfured apricots and prunes at 0° for a period of more than a year brought about no detectable loss of vitamin A content.

7. The vitamin A content of two varieties of yellow peaches, of prunes, and of apricots is shown to be relatively large, that of the apricots comparing favorably with the best figures reported for spinach, egg yolk, or butter. The peaches and prunes had less vitamin A than the apricots but as much or more than tomatoes, bananas, or lettuce.
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