Vitamin A
in Wyoming Butter

University of Wyoming
AGRICULTURAL
EXPERIMENT STATION

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ADDRESS: DIRECTOR OF EXPERIMENT STATION, LARAMIE, WYOMING
Butterfat is consumed in sufficient quantities and contains enough carotene and vitamin A to contribute approximately one-third of the vitamin A requirements for the entire population of the United States.

An increase in the number of units of vitamin A in butterfat will improve diets and aid in the nutritional well-being of many people.

Improvement in the quality of roughages which are fed to dairy cattle is a sure and economical way to raise the vitamin A potency of butterfat.

Butter may be used as a gauge for measuring the vitamin A potency of butterfat consumed in other dairy products such as whole milk, cheese, ice cream, and condensed milk.
In 1941 the Feed and Nutrition Board of the National Research Council wished to ascertain the importance of butter as a source of vitamin A in the diet of the people of the United States. The agricultural experiment station in 21 states, the U. S. Bureau of Dairy Industry, and the U. S. Office of Experiment Stations started a nationwide survey, and this bulletin represents the work done by the Wyoming Agricultural Experiment Station as its part in the study. A report from the cooperating agencies may be found in the U.S.D.A. Miscellaneous Publication 571.

Review of Literature. A recent survey of food consumption shows that dairy foods contribute more than one third of the vitamin A requirements for the human population in the United States (9). This contribution is important because vitamin A is essential in the human diet. Lack of vitamin A is frequently the cause of such disorders as night blindness and gastro-intestinal upsets. Epithelial cells of the mucous membranes lose their ability to secrete normally and become dry and hardened. The eye is particularly susceptible, and a disease, known as xerophthalmia, results. The hardening, known as keratinization, may also occur in the respiratory, alimentary, or urino-genital tract. Children suffering from xerophthalmia have a dry scaly skin.

Vitamin A is found in the butterfat of all dairy products. The vitamin A potency of butterfat is due mainly to two substances—Beta carotene, a yellow pigment which is the main precursor of the vitamin in cattle feeds, and the colorless vitamin A itself which the cow has made from this plant precursor. The precursors of vitamin A are readily changed in the body, chiefly in the liver, yielding vitamin A. Foods generally owe their vitamin A values to the precursors which they contain. The quantity of carotene in the diet of the cow determines the amount of vitamin A in the butterfat. Table 1 shows a definite relationship between the carotene in feed and the vitamin A in milk, even though only about two per cent of the vitamin A taken in by the cow eventually appears in the milk.
TABLE 1.
Relation Between the Quantity of Carotene in the Feed and the Amount of Vitamin A in the Milk (8).

<table>
<thead>
<tr>
<th>Herd ration daily</th>
<th>Carotene in the feed</th>
<th>Vitamin A in the milk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milligrams*</td>
<td>International units</td>
</tr>
<tr>
<td>A.I.V. ration (see note 'a', table 2)</td>
<td>357</td>
<td>6,644</td>
</tr>
<tr>
<td></td>
<td>561</td>
<td>11,389</td>
</tr>
</tbody>
</table>

* 1 milligram carotene equivalent to 1,000 international units vitamin A

TABLE 2.
Effect of Winter Ration, A.I.V. Silage Ration (a), and Pasture on the Carotene and Vitamin A Content of Butterfat and Butter.

<table>
<thead>
<tr>
<th>Daily Ration</th>
<th>Carotene</th>
<th>Vitamin A</th>
<th>Calculated international units (c) vitamin A per pound of butter (80.5 percent fat).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter: 1 lb. grain to 3 1/2 lbs. milk; 3 lbs. corn silage per 100 lbs. live weight of cow; 1 lb. alfalfa hay per 100 lbs. live weight of cow.</td>
<td>4.2</td>
<td>4.0</td>
<td>8,398</td>
</tr>
<tr>
<td>A.I.V.: 1 lb. grain to 3 1/2 lbs. milk; A.I.V. silage fed ad lib.; 1/2 lb. alfalfa hay per 100 lbs. live weight of cow.</td>
<td>6.8</td>
<td>9.0</td>
<td>17,282</td>
</tr>
<tr>
<td>Pasture: Bluegrass pasture and grain only.</td>
<td>11.0</td>
<td>11.0</td>
<td>22,759</td>
</tr>
</tbody>
</table>

(a) A.I.V. silage is named for its sponsor and originator, A. I. Virtanen. It is made by adding hydrochloric and sulphuric acids to green alfalfa or soybeans and storing them as silages. The acid preserves the proteins and carbohydrates.

(b) One microgram equals .000001 gram; microgram per gram is also the equivalent of parts per million.

(c) An international unit of vitamin A was used as the equivalent of .6 microgram carotene or .25 microgram of vitamin A.

The wide range of carotene and vitamin A appearing in Table 2 gives some indication of the possible spread in vitamin content of market butter. The results of other investigations are similar to the one reported by Peterson et al. and need not be reported here.
Vitamin A in Butter. Since Vitamin A is concentrated in the fat portion of milk, it can be assumed that the butter made from the fat will contain nearly all of the vitamin that appears in the milk. The report by Peterson et al. (8) goes further and shows the wide variation in carotene and vitamin A content of butter fat due to the kind of feed given a cow. The extent of these variations is suggested in Table 2. The average carotene and vitamin A are expressed both in terms of micrograms per gram of butter fat and in terms of calculated international units per pound of butter.

Method of Determining the Vitamin A Potency of Butter. The chemical procedures used in the Wyoming and other surveys were recommended by a technical committee formed under auspices of the U. S. Department of Agriculture and the state experiment stations. This committee had been appointed to study available methods and to devise one which would be applicable to butter. In a publication (3) on food nutritional values, issued as recently as 1939, no numerical values for the vitamin content were included. Later publications (1, 5) reported vitamin A values in terms of international units.

For vitamin A determination the Committee recommended a modification of the method of Koehn and Sherman in which the Carr-Price reaction (2) with antimony tri-chloride was used. As a method for carotene determination, the Committee chose washing the carotene solution in petroleum ether with 92 per cent methyl alcohol or 94 per cent diacetone to separate the carotene from other pigments.

Final readings of both vitamin A and carotene were made on an Evelyn photoelectric colorimeter (4, 7). The readings were transposed to micrograms per gram by means of graphs drawn from previous determinations of pure vitamin A and carotene after several observations.

To obtain the number of international units in one pound of butter, the Committee used .6 microgram carotene and .25 microgram vitamin A each be taken as equal to one international unit. The .6 microgram of carotene value is based on a later determination than the value given in Table 1 and gives a higher vitamin A value to each unit of carotene. Through experiment, members of the Committee showed that only 93 per cent of pure vitamin A dissolved in butter was recovered, and they suggested that vitamin A values be increased by seven per cent to take care of the...
lost during analysis. The sum of the international units thus obtained was multiplied by 453.6, the number of grams per pound, to evaluate the international units per pound of butter.

Procedures Used in Conducting Survey. During 1944-45 eight Wyoming creameries sent a total of 75 one-pound prints of butter to the laboratory at the University of Wyoming for vitamin A analysis. The creameries represented a diverse group of farming and ranching areas in the state. In all cases, except in the southeastern part of the state, alfalfa hay made up the sole roughage. Summer forage consisted chiefly of native grass ranges. The altitude of the areas varied from 4,000 to 7,000 feet. The creameries represented the North Central area, east and west of the Big Horn Mountains; the extreme west, south of the Tetons; and the high valleys between the Medicine Bow and Laramie ranges. No appreciable difference was noted in the vitamin A potency of the butters from these several areas.

In order to find out how much vitamin A the butter in Wyoming could be expected to furnish in the diet, it was necessary to know the relative amounts of butter produced in the state by months. An aliquot sample could then be calculated for the different seasons and a weighted average secured. The amounts of butter reported by months in 1943 by George Knutson, agricultural statistician with the U. S. Bureau of Agricultural Economics, Cheyenne, Wyoming, showed that 34.5 per cent of the butter was produced during the months of December through April and 65.5 per cent produced during the remaining months. While these percentages may vary from year to year, especially in recent years, these figures are fairly representative over a long period. They are, therefore, used in computing the weighted average of carotene and vitamin A of butter produced in Wyoming.

Results. Monthly and seasonal data for all samples are shown in Table 3. The amounts of carotene and vitamin A actually found in the butter are expressed in terms of micrograms per gram. The potency per pound of butter is a corrected figure which allows for loss of vitamin A during the analysis and is expressed in terms of international units. Every month except August is represented.

Table 3 reveals a wide variation in vitamin A potency of butter in Wyoming. From a low point of 8,886 units in April, it reaches a high of 16,562 units per pound in July. After the month of April the rise in vitamin A potency is sudden, but the drop in
the fall months is low; in fact, potencies below 10,000 units per pound are not reached before January.

Potencies for the winter months (December through April) average just below 10,000 units. The summer potencies (May through November) rise above 14,000 units and show a weighted mean annual figure of 12,783 international units per pound of butter.

**TABLE 3.**
Carotene and Vitamin A Analysis of Wyoming Creamery Butter 1944-45.

<table>
<thead>
<tr>
<th>Production Period</th>
<th>Carotene per gram</th>
<th>Vitamin A per gram</th>
<th>Corrected for loss of vitamin A in analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>micrograms</td>
<td>micrograms</td>
<td>I. U. per pound (c)</td>
</tr>
<tr>
<td>January</td>
<td>2.03</td>
<td>4.20</td>
<td>9,729</td>
</tr>
<tr>
<td>February</td>
<td>2.15</td>
<td>3.96</td>
<td>9,351</td>
</tr>
<tr>
<td>March</td>
<td>2.38</td>
<td>3.87</td>
<td>9,350</td>
</tr>
<tr>
<td>April</td>
<td>2.05</td>
<td>3.76</td>
<td>8,886</td>
</tr>
<tr>
<td>May</td>
<td>3.26</td>
<td>5.54</td>
<td>13,273</td>
</tr>
<tr>
<td>June</td>
<td>3.77</td>
<td>6.17</td>
<td>14,888</td>
</tr>
<tr>
<td>July</td>
<td>4.90</td>
<td>6.59</td>
<td>16,562</td>
</tr>
<tr>
<td>August</td>
<td>(d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>3.38</td>
<td>5.34</td>
<td>12,974</td>
</tr>
<tr>
<td>October</td>
<td>3.48</td>
<td>5.38</td>
<td>13,127</td>
</tr>
<tr>
<td>November</td>
<td>3.88</td>
<td>4.85</td>
<td>12,396</td>
</tr>
<tr>
<td>December</td>
<td>2.39</td>
<td>5.04</td>
<td>11,640</td>
</tr>
<tr>
<td>Average of winter samples (a)</td>
<td>2.21</td>
<td>4.18</td>
<td>9,830</td>
</tr>
<tr>
<td>Average of summer samples (b)</td>
<td>3.79</td>
<td>5.80</td>
<td>14,185</td>
</tr>
<tr>
<td>Mean for annual output</td>
<td>3.28</td>
<td>5.28</td>
<td>12,783</td>
</tr>
</tbody>
</table>

(a) Weighted potency for butter produced from December to April inclusive. 32.2 per cent of the state's annual output.
(b) Weighted potency for butter produced from May to November inclusive. 67.8 per cent of the state's annual output.
(c) 93.0 per cent vitamin A recovery.
453.6 grams per pound.
1 microgram carotene per gram equals 756 international units per pound.
1 microgram vitamin A per gram equals 1814.4 international units per pound uncorrected for loss in analysis.
1 microgram vitamin A per gram equals 1951.0 international units per pound corrected for loss in analysis.
(d) Analysis assumed to be the same as for June.
The results from 14 states representing 63.7 per cent of the nation-wide output of creamery butter for 1943-44 have been published (9) and are reported in Table 4. Wyoming’s output for the same period was approximately 2.8 million pounds. The regions represented in the vitamin A survey produce 97.2 per cent of the total national butter output. Most of the states not reported here have made a study of the vitamin A content of market and farm butter was found to be similar to the vitamin A content of creamery butter.

**TABLE 4.**

Vitamin A Potency of Creamery Butter During Winter and Summer Months in 14 States.

<table>
<thead>
<tr>
<th>State</th>
<th>1942-43 avg. yearly butter production (million lbs.)</th>
<th>Average Vitamin A Potency per pound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1942-43 avg. yearly butter production</td>
<td>Winter Butter International Units</td>
</tr>
<tr>
<td>Minnesota</td>
<td>304.4</td>
<td>10,808</td>
</tr>
<tr>
<td>Iowa</td>
<td>241.0</td>
<td>10,946</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>151.2</td>
<td>10,663</td>
</tr>
<tr>
<td>Nebraska</td>
<td>93.3</td>
<td>11,287</td>
</tr>
<tr>
<td>Kansas</td>
<td>74.7</td>
<td>11,606</td>
</tr>
<tr>
<td>Ohio</td>
<td>69.5</td>
<td>9,698</td>
</tr>
<tr>
<td>California</td>
<td>43.2</td>
<td>15,140</td>
</tr>
<tr>
<td>Idaho</td>
<td>37.1</td>
<td>13,312</td>
</tr>
<tr>
<td>Washington</td>
<td>32.0</td>
<td>12,162</td>
</tr>
<tr>
<td>Oregon</td>
<td>28.2</td>
<td>12,899</td>
</tr>
<tr>
<td>Montana</td>
<td>12.7</td>
<td>18,636</td>
</tr>
<tr>
<td>Mississippi</td>
<td>4.0</td>
<td>12,014</td>
</tr>
<tr>
<td>N. Carolina</td>
<td>1.8</td>
<td>9,674</td>
</tr>
<tr>
<td>Louisiana</td>
<td>.8</td>
<td>12,873</td>
</tr>
<tr>
<td>Total or Avg.</td>
<td>1,093.9</td>
<td>11,160</td>
</tr>
</tbody>
</table>

**Discussion.** The great variation in the vitamin A potency of Wyoming butter from month to month and from season to season emphasizes that feed must be an important factor in determining that potency. The early work of Peterson et al. (8) likewise gives considerable weight to feed as a factor influencing vitamin A potency of butter. The Peterson work showed butter produced from cows getting grain, corn silage, and alfalfa hay con-
Vitamin A in Wyoming Butter

tained 8,398 international units of vitamin A per pound. When
the ration was changed to include feeds of a greater carotene poten-
cency, the vitamin A content of the butter increased to 17,282
international units per pound.

Both the Wyoming and the Peterson studies suggest that the
vitamin A content of butter can be increased by furnishing the
cows with better roughages. In Wyoming, where alfalfa forms an
important part of dairy herd roughages, an easy way of getting
more carotene and vitamin A into the ration is through more care-
ful curing and storing to preserve the green color in the hay.

No matter how well hay has been cured or stored, it gradually
loses its vitamin A value. Fresh moisture-free alfalfa at the Wyom-
ing Experiment Station contained 300 micrograms per gram dur-
ing the growing season, while moisture-free alfalfa hay, analyzed
late in the winter, contained only 7.2 micrograms per gram. The
gradual falling off in the vitamin A content of hay during storage
is reflected in a decline in vitamin A in butter during the fall
months. This decline is gradual, although it might be expected to
be sudden as a result of changing cows abruptly to dry feed. The
gradual decline in vitamin A body reserves of the cow may be a
cushioning factor in preventing any sudden lowering of the vitamin
A level of butter at the time the cows are changed to winter feed.

The vitamin A potency of butter produced in Wyoming is
less than the national average of 15,000 international units per
 pound (9). Taking into consideration the comparatively high alti-
tude, with its short growing season, and the dry grass ranges used
for pasture, the Wyoming analyses are reasonably close to the
national average. It may be assumed from the wide variation in
check samples from various experiment stations that too much
emphasis should not be given to exact figures in vitamin A and
carotene analyses. Further investigation may reveal the cause of
the apparent low figures in the Wyoming analyses.

Summary. Analysis of 75 one-pound samples of butter from
eight creameries widely scattered over Wyoming showed con-
siderable seasonal variation—ranging from a low of 8,886 inter-
national units in April to a high of 16,562 international units of
vitamin A per pound in July. The weighted average for the winter
months, December through April, was 9,830 international units. That
for the summer and fall, during the months of May through
November, was 14,185 international units of vitamin A per pound
of butter. The weighted mean for the entire year was just short of 13,000 international units.

ACKNOWLEDGMENT: Graphs for interpolating carotene and vitamin A values were worked out by C. S. Gilbert of the Research Chemistry Department. Mr. Gilbert and Dr. Karl Swingle of the Research Chemistry Department operated the photoelectric colorimeter in the determination of carotene and vitamin A in the butter samples. Miss E. J. Thiessen of the Experiment Station Home Economics staff aided in drafting the manuscript for this report.

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