RESATIVE VALUE OF VITAMIN A AND CAROTENE FOR SUPPLYING THE VITAMIN A REQUIREMENTS OF SWINE DURING GESTATION AND BEGINNING LACTATION

D. B. Parrish, C. E. Aubel, J. S. Hughes and J. D. Wheat

Kansas Agricultural Experiment Station

The National Research Council's (1944) daily vitamin A allowances for pregnant gilts and sows are 13,000 I.U. vitamin A or 20 mg. carotene. Thus, based on the factor of 1.6 as the approximate conversion of crystalline carotene to vitamin A, the allowance for this provitamin is 2.5 times that for preformed vitamin A. Allowances in the foregoing ratio are in harmony with results of earlier vitamin A studies of mammalian species (Guilbert, Howell and Hart, 1940). It was recognized, however, that the allowances for gilts and sows were based upon a limited amount of data, mostly that on growing pigs; therefore it seemed desirable to obtain further information on the relative values of vitamin A and carotene for supplying the vitamin A needs of swine during gestation and early lactation. Data from an investigation of this problem are reported herein.

Experimental Procedures

Two trials were conducted using 15 different Duroc gilts each time. The experimental subjects were removed from pasture in the Fall and placed in dry lot for 3 to 4 weeks, after which time they were divided into three lots and the feeding of experimental diets was begun. The gilts were bred about one month later, at which time they weighed approximately 300 lbs. Animals in lot I, the check lot, were housed together and were fed tankage, yellow corn, salt, and alfalfa hay *ad libitum*.

Animals in lots II and III were housed in individual pens consisting of shelter in a barn and a paved outside lot. Wood shavings were

---

1 Contribution No. 434, Department of Chemistry, No. 176, Department of Animal Husbandry and No. 118, Department of Veterinary Medicine.
2 We are indebted to Distillation Products Inc. for supplying distilled vitamin A concentrates and to American Chlorophyll Inc. for supplying a crystalline carotene preparation used in trial 1. We also wish to acknowledge the R. P. Scherer Corp., Gelatin Products Division, for the generous supply of capsules containing the vitamin A and carotene supplements used in trial 2.
3 The authors wish to acknowledge the excellent cooperation of Mr. Claude Dunn in assisting with the feeding and management of the experimental animals.
4 Hay used in trial 1 contained 7.5 mg. carotene/100 g. at the close of the trial; that in trial 2, 14.7 mg.
used as bedding. The basal ration for lots II and III was of the following percentage composition: ground white corn, 81.5; solvent extracted soybean oil meal, 14; brewer's yeast, 1.5; skim milk powder, 2.5; iodized salt, 0.16; bone meal, 0.16; calcium carbonate, 0.16; and vitamin D. The amount of ration fed was adjusted to the weight and condition of the gilt, according to normal practices.

Vitamin A was given to gilts in lot II and carotene to those in lot III at a level of 6500 I.U. daily in trial 1 and 7100 I.U. daily in trial 2. The amounts of supplement given were selected so that animals receiving carotene would get it near marginal levels. Under these conditions it was believed any differences in performance would show up.

During trial 1, the vitamin supplements, crystalline carotene and distilled vitamin A concentrate, were dissolved in corn oil and pre-mixed with soybean meal so that a measure of 20 g. supplied the daily allotment. The supplements were prepared at monthly intervals and stored in the dark at \(-12^\circ\) C. A fresh supply for feeding was removed from storage and taken to the barn each week. In trial 2, small capsules containing the daily allotment of the vitamin in corn oil were used. The contents of one of these capsules were mixed with the ration of each individual gilt once daily.

Samples of blood were taken from each gilt at the time of farrowing, and from many of them additional samples were taken at other times during the trial. Blood was centrifuged to obtain serum, which was stored at 4°C until analyses could be made, usually within two days. Colostrum was obtained by milking 2 to 6 teats as completely as possible while the gilt was farrowing. Pitocin was used to induce colostrum let-down (Ely and Petersen, 1941) in a few cases, but it seemed to be of little help, possibly because the gilts were in labor and their systems already under the influence of this hormone. One pig of each litter was sacrificed before it had consumed colostrum, and another was sacrificed 4 days later for obtaining blood and liver samples. Blood from the newborn pigs was treated in the same manner as that of the gilts; livers were frozen until analyzed, always within 10 days.

The Kimble (1939) method for determining vitamin A in blood serum was used, since similar results were obtained on swine blood serum regardless of whether or not the samples were saponified in the procedure (Parrish et al., 1948). Vitamin A was determined in colostrum by the modified procedure used by Parrish et al. (1949), except that 10 ml. of sample was saponified by heating. Livers, trimmed
of connective tissue and large blood vessels, were homogenized in a Waring blender; a 10-g. sample was saponified, extracted and analyzed in a manner similar to that for colostrum.

Criteria used for estimating the relative values of vitamin A and carotene for gestation and early lactation were: concentration of vitamin A in blood serum and in colostrum of gilts, concentration of vitamin A in blood serum and in livers of new-born and of 4-day-old pigs and condition of gilts and baby pigs.

Results

Results obtained in trial 2 indicated that feeding gilts the carotene supplement for one month caused only relatively small declines in the original serum vitamin A levels. However, after this supplement was given for three months the vitamin A levels in the serum were only 13.8 μg. per 100 ml., which was about six-tenths of that contained in the serum of gilts of the other two dietary groups.

The average vitamin A concentrations (table 1) in serum and in colostrum of gilts at the time of farrowing and in serum and livers of baby pigs usually were smaller in animals of vitamin A supplemented groups (lot II) than in those of check groups (lot I). Differences are significant, however, only for vitamin A levels in livers of the 4-day-old pigs of trial 2. Thus, as judged by the criteria selected, the overall value of vitamin A at levels of 6500 or 7100 I.U. daily was similar to that of natural sources of vitamin A as supplied by the check ration. Gilts in both lots I and II appeared to be in a satisfactory condition and averaged, respectively, 9.1 and 8.2 pigs per farrowing.

Colostrum from dams receiving carotene (lot III) contained only one-half to three-fourths as much vitamin A as did colostrum from dams of the other two lots. Blood serum vitamin A concentrations of gilts receiving carotene were only about one-half of those of gilts receiving either the vitamin A or the check ration. Furthermore, vitamin A concentrations in serum of new-born and of 4-day-old pigs from dams receiving carotene also were approximately one-half of those of pigs from dams in lots I and II, and vitamin A content of livers of pigs from carotene-supplemented dams was markedly lower than that of livers of pigs from dams in the other two dietary groups.

Gilts receiving the carotene supplement appeared normal at farrowing time, but in each trial one animal failed to show pigs. However, parturient dams of this lot farrowed an average of 9.8 healthy pigs, more pigs than dams of either of the other two lots. Three of the four
TABLE 1. CONCENTRATIONS OF VITAMIN A IN BLOOD SERUM AND COLOSTRUM OF GILTS AT TIME OF FARROWING AND IN BLOOD SERUM AND LIVERS OF NEWBORN AND OF 4-DAY-OLD PIGS

<table>
<thead>
<tr>
<th>Trial</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lot 1</td>
<td>Lot 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ration Supplement</th>
<th>Check</th>
<th>Vitamin A</th>
<th>Carotene</th>
<th>Check</th>
<th>Vitamin A</th>
<th>Carotene</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in gilt's blood serum</em>, μg./100 ml.</td>
<td>17.7</td>
<td>±1.28</td>
<td>20.0</td>
<td>±2.39</td>
<td>10.3</td>
<td>±3.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in colostrum</em>, μg./100 ml.</td>
<td>221</td>
<td>±14.8</td>
<td>191</td>
<td>±14.6</td>
<td>103</td>
<td>±18.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in new-born pig's blood serum</em>, μg./100 ml.</td>
<td>12.5</td>
<td>±0.75</td>
<td>11.9</td>
<td>±0.83</td>
<td>6.7</td>
<td>±2.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in 4-day-old pig's blood serum</em>, μg./100 ml.</td>
<td>33.4</td>
<td>±2.97</td>
<td>30.5</td>
<td>±2.99</td>
<td>17.7</td>
<td>±4.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in new-born pig's liver</em>, μg./g.</td>
<td>10.7</td>
<td>±1.13</td>
<td>6.8</td>
<td>±1.96</td>
<td>1.6</td>
<td>±1.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in 4-day-old pig's liver</em>, μg./g.</td>
<td>18.9</td>
<td>±2.44</td>
<td>18.3</td>
<td>±4.50</td>
<td>3.8</td>
<td>±2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vitamin A in 4-day-old pig's liver</em>, μg./liver</td>
<td>821</td>
<td>±116</td>
<td>808</td>
<td>±182.6</td>
<td>163</td>
<td>±31.5</td>
</tr>
</tbody>
</table>

1 Five animals per lot, except in each trial Lot III contained only 4 animals by farrowing time.
2 Standard error.
3 One gilt refused to care for her pigs; only 4 pigs available at this stage.
baby pigs that died with scours during trial 2 were from dams in
lot III (carotene supplemented), but the infection was general in the
area and probably was not related to the experimental treatment. In
spite of the fact one gilt of lot III was slow coming into milk and
three of her pigs were lost, apparently from starvation, slightly more
pigs were raised per dam of lot III than by those of lot II.

Analyses of serum of 8 gilts (all three lots of animals used in
trial 2 being represented) during terminal stages of gestation and
early stages of lactation revealed that in all animals the vitamin A
concentrations were smallest at the time of farrowing. The average
changes\(^5\) were 177, 154, 132, 100, 159 and 162 on, respectively, the
18th, 6th and 2nd days ante partum and the 0, 2nd and 4th days post
partum. Vitamin A concentrations in the serum of gilts of lots I and
II, trial 2, on the 4th day post partum were nearly the same as 16 to
22 days ante partum (27.6 \(\mu\)g. and 25.1 \(\mu\)g., respectively, post partum
and 28.6 \(\mu\)g. and 24.2 \(\mu\)g., respectively, ante partum). In contrast,
vitamin A concentrations in serum of animals of lot III were only
9.3 \(\mu\)g and 15.0 \(\mu\)g at the two respective periods.

When results from the two trials were pooled, a correlation of 0.60
was found for vitamin A in blood serum of gilts at the time of farrow-
ing and in their colostrum. A correlation of 0.83 was found for vitamin A
in blood serum of gilts and in that of their new-born pigs. The correla-
tion of vitamin A concentration in serum of gilts and in liver of
new-born pigs was 0.56, only a slightly larger value (0.58) being found
when level in serum and total content per liver were compared. The
correlation of vitamin A in blood serum and in liver of new-born
pigs was 0.67. Correlation of vitamin A at birth and at 4 days of
age in pig’s blood serum was 0.55 and in pig’s liver was 0.70.

Discussion

At the time of parturition the vitamin A concentration in serum
and in colostrum of gilts of both lots I and II were essentially as
large as, or larger than, those previously reported for sows and
gilts fed typical herd feeds (Bowland et al., 1949; Braude et al.,
1945–46; Eaton et al., 1949; Leucke et al., 1947; Thomas et al., 1947;
and Whiting et al., 1949). Some of the higher values observed in the
present study possibly are due to the fact that only gilts were used,
for if swine respond similarly to cattle (Parrish et al., 1949), it would
be expected that vitamin A concentrations would be higher in colostrum

---

\(^5\) Some data had to be adjusted (Latschar et al., 1949) before they could be summarized.
Values are compared to a base value of 100 which represents the vitamin A level of the blood
sample taken at time of farrowing.
of gilts than in that of older sows. Blood serum and liver vitamin A concentrations of new-born pigs from gilts in lots I and II likewise were as large as, or larger than, those reported by Eaton et al. (1949), Thomas et al. (1947), and Whiting et al. (1949) for pigs from dams fed normal feeds.

Although vitamin A levels in colostrum of gilts receiving only 6500 or 7100 I.U. of vitamin A daily as carotene (lot III) and in serum of their new-born pigs were lower than values on colostrum and serum of pigs from the other two lots, they were not markedly lower than reported for animals receiving normal feeds by the authors previously cited. The carotene supplement fed the dam, however, was adequate for only about one-fourth as much liver storage of vitamin A in new-born pigs, as in new-born pigs of the check lot or of those from dams receiving typical swine rations, as reported by the aforementioned authors.

It is interesting that blood and liver stores of vitamin A in new-born pigs from gilts receiving carotene (lot III) were as large as, or larger than, those reported for new-born calves, kids or lambs from dams fed normal rations (Moore and Berry, 1944; Parrish et al., 1946–47; Pope et al., 1949; Spielman et al., 1949; Thomas et al., 1947; Whiting et al., 1949; Wise et al., 1946; Wise et al., 1948). After colostrum and milk were consumed for the first four postnatal days, the increases of vitamin A in blood serum and in livers of the pigs of gilts receiving the carotene supplement were comparable to findings on new-born calves whose dams received normal rations. The declines in vitamin A levels in serum of gilts during the late stages of gestation and the increases following parturition are similar to observations on tocopherols (Latschar et al., 1949) and on vitamin A and carotenoids (Kuhlman and Gallup, 1944; Sutton et al., 1945; Wise et al., 1947) in serum of cattle. In swine, however, the minimum values appeared to have occurred nearer to the time of parturition than observed in cattle.

Approximately 7000 I.U. of preformed vitamin A daily seemed to be adequate for pregnant gilts, as judged by concentrations of vitamin A in their blood serum and in their colostrum, by their general health and ability to recover to normal serum vitamin A levels after farrowing, and by concentrations of vitamin A in blood serum and livers of new-born and 4-day-old pigs. The requirement probably is increased if vitamin A intake of the dam before pregnancy is inadequate. Based on these same criteria, 7000 I.U. of carotene daily were not as effective as preformed vitamin A, particularly for liver storage in the baby
VITAMIN A AND CAROTENE FOR SWINE

pigs. There was no positive evidence, however, that gilts in the carotene group (lot III) or their pigs suffered from a deficiency of vitamin A. Results with gilts tend to substantiate previous findings with growing pigs (Guilbert et al., 1937) that the requirements of swine for carotene are higher than for vitamin A.

Summary

In two different trials a comparison was made of the relative values of vitamin A and carotene, when added to a low-carotenoid basal diet at levels of 6500 or 7100 I.U. daily, for supplying the vitamin A for gilts during gestation and early lactation. Results on these animals also were compared with those on gilts of a check lot that received a typical herd ration. Criteria for estimating the relative values of vitamin A and carotene were: concentration of vitamin A in blood serum and in colostrum of gilts, concentration of vitamin A in blood serum and in livers of new-born and of 4-day-old pigs, and condition of gilts and baby pigs.

Vitamin A concentrations in blood serum of vitamin A supplemented gilts at parturition, in their colostrum and in serum and livers of their new-born and 4-day-old pigs, were essentially the same as vitamin A concentrations in similar materials from animals of the check lot, the values being significantly lower only for vitamin A in livers of 4-day-old pigs from dams of the vitamin A dietary group in one trial.

Vitamin A concentrations in colostrum of gilts receiving crystalline carotene were only one-half to three-fourths of those in colostrum from dams of the other dietary groups. Concentrations of vitamin A in blood serum of carotene-supplemented dams at the time of parturition and in serum of their new-born and 4-day-old pigs were approximately one-half of those of animals of the vitamin A and the check lots. Concentrations of vitamin A in livers of new-born and 4-day-old pigs from carotene-supplemented dams were less than one-fourth of those in livers of similar pigs from dams of the other two lots. Although there was no positive evidence that the carotene-supplemented gilts or their pigs suffered from a vitamin A deficiency, the data clearly shows that unit for unit carotene is less effective than preformed vitamin A as a vitamin A supplement for swine during gestation and early lactation.

Vitamin A concentrations in blood serum of the dams decreased as parturition approached and increased during the days immediately following parturition.
Literature Cited


Whiting, F., J. K. Loosli and J. P. Willman. 1949. The influence of tocopherols
upon the mammary and placental transfer of vitamin A in sheep, goat and pig. *Journal of Animal Science* 8:35.

