[Reprinted from FOOD RESEARCH, 1953, Vol. 18, No. 6, Pages 618-624]

# NUTRITIVE VALUE OF CENTRAL AMERICAN CORNS. IV. THE CAROTENE CONTENT OF THIRTY-TWO SELECTIONS OF GUATEMALAN CORN[a]



RICARDO BRESSANI, ANDRÉS A. CAMPOS
*Instituto de Nutrición de Centro América y Panamá (INCAP)*

ROBERT L. SQUIBB
*Instituto Agropecuario Nacional*

AND

NEVIN S. SCRIMSHAW
*Pan American Sanitary Bureau and INCAP*
*Guatemala, Central America*

(Manuscript received May 6, 1953)

The pro-vitamin A activity of corn *(Zea mays)* is of considerable importance to Central America. Dietary surveys and clinical and laboratory studies *(7, 8)* indicate that vitamin A deficiency may be widespread. In some groups of people 75% of the diet by weight may consist of corn. The significantly higher serum carotene levels observed in Guatemalan school children compared to those of El Salvador have been attributed to the relatively high carotene content of the yellow corns popular in Guatemala, in contrast to the very low carotene content of the white corns commonly used in El Salvador *(8)*. Because of its practical importance in the local diet, the analysis of 32 varieties of Guatemalan corn for their β-carotene content was undertaken.

Since there is ample evidence that the vitamin A activity of corn is quite different from either the content of total carotenoids or the β-carotene value as measured by routine food analyses techniques, the biological vitamin A activity of one of the varieties was estimated for comparison purposes using chick growth assay.

## MATERIALS AND METHODS

Of the 32 corn varieties of different origins 23 varieties including a cross between a Guatemalan and a United States commercial hybrid were planted at an altitude of approximately 5,000 feet in Antigua, Guatemala, during 1947, 1948 or 1949. The characteristics, origin, and sampling of these corns and those of the variety TGY have been described previously *(5)*. An additional 8 collections of corn labeled INCAP were harvested at Santa Maria Cauque, Department of Sactepequez, during the fall of 1950 in fields with an average altitude of 6,500 feet. These corns were all open polinated.

The concentration of β-carotene was measured at 440 mμ in an Evelyn Colorimeter after extraction, purification, adsorption, and elution of the pigment with 5% acetone in petroleum ether on a celite-magnesium oxide column. The method is essentially that of Guilbert *(6)* as modified by Peterson *et al.* *(11)*. All carotene values cited are the average of two determinations and are expressed on the basis of 10% moisture content.

[a]A cooperative study in which 24 of the corn samples and data relating to their origin were furnished by Dr. Irving E. Melhus, Director, Iowa State College Tropical Research Center, Antigua, Guatemala. The project was aided by a research grant from the Instituto de Fomento de la Producción (INFOP) Guatemala, Central America. Contribution I-25 from the Instituto de Nutrición de Centro América y Panamá.

Quackenbush *(12)*, in a preliminary study by chemical fractionation methods, (Table 1) explored the relationship between total carotenoids as measured at 468 mμ, β-carotene, cryptoxanthol, and other pigments in 4 corn samples reported here.

From the data of Table 1, it was calculated that the 2 samples of TGY contained 6.24 and 4.98 mcg. of vitamin A activity per g. This variety was assayed using 2 chick trials of 5-week duration. New Hampshire straight run baby chicks, 3 days old, were banded and distributed by weight among the various experimental groups. The chicks were housed in special, electrically heated, all-wire cages with raised screen bottoms. Feed and water were provided *ad libitum* and weekly individual weights were obtained.

TABLE 1

**Carotenoid fraction analysis of three varieties of Guatemala corn** [b]

| Corn variety | β-carotene | Cryptoxanthol | Luteol | Zeaxanthol | Unidentified |
|---|---|---|---|---|---|
| | *mcg./g.* | *mcg./g.* | *mcg./g.* | *mcg./g.* | *mcg./g.* |
| TGY[c] | 2.94 | 6.61 | 2.45 | 5.28 | 0.74 |
| TGY | 2.04 | 5.88 | 1.03 | 3.92 | 4.68 |
| 12A–46 | 0.20 | 0.96 | 2.43 | 1.50 | 0.95 |
| 15A–46 | 0.25 | 0.27 | ...... | 0.14 | ...... |

[b] Data furnished by F. W. Quackenbush from analysis carried out at Purdue University.
[c] Tiquisate Golden Yellow.

In experiment 1, the baby chicks were fed an all-vegetable protein basal ration. In experiment 2, a vitamin test casein was added to increase the growth rate of the chicks. These rations were as follows:

| Basal Ration, Experiment 1 | g. | Basal Ration, Experiment 2 | g. |
|---|---|---|---|
| Corozo oil meal | 40 | Corozo oil meal | 15 |
| Sesame oil meal | 12 | Sesame oil meal | 30 |
| Cottonseed oil meal | 12 | Cottonseed oil meal | 5 |
| Sorghum | 32.3 | Casein VT | 4 |
| | | White corn | 42.3 |

Both rations also contained the following: bone meal, 1 g.; $CaCO_3$, 1 g.; NaCl with 4% of $MnSO_4$, 1 g.; Delsterol, 200 mg.; choline, 125 mg.; thiamine, 0.2 mg.; riboflavin, 0.35 mg.; pantothenic acid, 1.2 mg.; nicotinic acid, 1.5 mg.; and pyridoxine, 0.35 mg.

The sorghum in experiment 1 and the white corn in experiment 2 were replaced with corresponding amounts of the corn variety TGY as indicated in Table 4.

## RESULTS

The β-carotene concentrations found in the 24 varieties of Guatemala corn are given in Table 2. Since some samples contained seeds that varied in color, the color listed is the prevailing color of the seed lot. The β-carotene in the yellow varieties ranged from 0.020 to 0.210 mg. per 100 g. with an average of 0.115 (s 0.062). The white corn selections grown at Antigua varied in β-carotene content from 0.010 to 0.096 mg. per 100 g. with an average of 0.033 (s 0.024). In the collections of INCAP the range for yellow and deep red hull and yellow endosperm was 0.131 to 0.177 mg. per 100 g., with an average of 0.157, and for the white and black hulled corns was 0 to 0.024 mg. per 100 g., with a mean value of 0.014 mg. per 100 g. The β-carotene content of the deep yellow variety TGY grown in 5 different localities, Table 3, ranged from 0.180 to 0.380 mg. per 100 g. with an average of 0.300 mg. per 100 g.

For the biological assays, the number of chicks, their mortality, weight gain, and feed efficiency are presented in Table 4. Comparison of the growth rates of the chicks fed various levels of corn and standard vitamin A indicates that the samples of TGY contained approximately 800 I. U. of vitamin A per 100 g. in the first trial and 1,250

**TABLE 2**

**The β-carotene content of 32 varieties of corn**

| Grown at Antigua, Guatemala | | | | | | | | | Grown at Sta. Maria Cauque, Guatemala | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variety No. | | Carotene | Variety No. | | Carotene | Variety No. | | Carotene | Variety No. | | Carotene |
| | | *mg./100 g.* | | | *mg./100 g.* | | | *mg./100 g.* | | | *mg./100 g.* |
| 206–44 ⊗ | W | 0.038 | 166–44 O.P. | W | 0.010 | 92–44 O.P. | W | 0.027 | INCAP 18 | Y | 0.151 |
| 159–44 (2s) | Y | 0.159 | 31–44 # | Y | 0.058 | 129A–46 # | Y | 0.085 | INCAP 19 | W | 0.023 |
| 47A–46 O.P. | W | 0.019 | 20–47 ⊗ | Y | 0.092 | 12A–46 # ⊗ | Y | 0.172 | INCAP 22 | B | 0.007 |
| 1470–45 # | W | 0.047 | 1483–45 ⊗ | W | 0.018 | TGY | Y | 0.162 | INCAP 409 | B | 0.024 |
| 25A–46 ⊗ | Y | 0.027 | 21A–46B # | W | 0.096 | 1626–45 O.P. | W | 0.018 | INCAP 416 | W | 0.000 |
| 92A–46 # ⊗ | Y | 0.020 | 10A–46 O.P. | Y | 0.210 | 7A(WF9×38–11) | Y | 0.194 | INCAP 417 | r | 0.169 |
| 192–44 # ⊗ | Y | 0.109 | 142–48 O.P. | Y | 0.135 | 26A–46⊗ | W | 0.016 | INCAP 418 | R | 0.177 |
| 15A–46 O.P. | Y | 0.070 | 118A–46 # | W | 0.032 | 200–47 O.P. | W | 0.046 | INCAP SMC | Y | 0.131 |

Legend:
W=white kernel
Y=yellow kernel
B=black hulled kernel
r=light red hulled kernel
R=dark red hulled kernel

I. U. in the second. This agrees satisfactorily with the chemical estimation of Quackenbush of 1,040 I. U. of vitamin A activity per 100 g. (6.24 mcg./g.) and 830 I. U. (4.98 mcg./g.) for 2 other samples of this variety. The mortality rates and clinical evidence of avitaminosis A in the chicks fed at the higher levels of both corn and vitamin A standard give added support to the growth data.

TABLE 3

$\beta$-Carotene content of the variety TGY grown in five different localities

| Sample No. | Location | Altitude | Content |
|---|---|---|---|
| | | *feet* | *mg./100 g.* |
| INCAP-271 | Coatepeque | 100 | 0.380 |
| INCAP-275 | Cuyuta | 100 | 0.350 |
| INCAP-266 | Tiquisate | 150 | 0.300 |
| INCAP-298 | Retalhuleu | 200 | 0.290 |
| INCAP-276 | Antigua | 4,953 | 0.180 |

## DISCUSSION

The values reported for the $\beta$-carotene content of the corns are not the full measure of their pro-vitamin A activity. This is due to the fact that the method for $\beta$-carotene does not measure the cryptoxanthol present although it is commonly considered to be approximately half as active biologically as $\beta$-carotene. On the other hand when total carotenoids are measured other pigments absorbed in the same region of the spectrum are credited with a vitamin A activity they do not possess.

The value of estimating the vitamin A activity of corn by the chemical fractionation of the total carotenoid present is demonstrated by the chick assay data. They confirm the total pro-vitamin activity of the variety TGY as estimated by the chemical method of Quackenbush when cryptoxanthol is calculated to have one-half the pro-vitamin A activity of $\beta$-carotene.

The influence of environmental factors, including soils, on the $\beta$-carotene content of corns is suggested by the data presented for one lowland variety, Tiquisate Golden Yellow (TGY), which was grown in 4 different lowland areas and one highland area. The data indicate that the $\beta$-carotene content of this lowland corn was reduced approximately 48 to 53% when it was grown at 5,000 feet. The higher value for this corn when grown in the lowland as compared to the highland location may be related to its better adaptation to the former locality.

Although environmental factors are important, the pro-vitamin A activity of corn is also greatly influenced by some of the factors that control the development of yellow endosperm. Mangelsdorf and Fraps *(10)* showed that there is a direct quantitative relationship between the amount of pro-vitamin A and the number of genes for yellow pigment. These findings were confirmed by Kemmerer *et al. (9)* who stated that the number of genes present for yellow color in corn directly affects the amount of vitamin A-active carotenoid pigment, but does not affect appreciably the relative proportions of alpha- and beta-carotene and cryptoxanthol. Randolph and Hand *(13)* showed that doubling the number of chromosomes in pure yellow corn caused a 40% increase in the carotenoid content of corn grain.

Until relatively recently corn breeders were concerned mainly with obtaining high yields and resistance to disease and drought. Aurand *et al.* *(3, 4)* have shown that when attention is given to both yield and carotene, certain high yielding corn lines show relatively high carotene content. Since possibilities exist for the selection of corns of higher pro-vitamin A content *(14, 15, 16)*, as well as yield, the determination of β-carotene and cryptoxanthol is also of potential value to the Agricultural Experiment Stations in Central America that wish to develop superior corn varieties.

TABLE 4

**Growth and mortality of baby chicks supplemented with a vitamin A standard and different percentages of yellow corn (TGY)**

| Addition to ration | Number of chicks | | Average weight | | Feed efficiency[f] | Number chicks with avitaminosis A |
|---|---|---|---|---|---|---|
| | Start | End | Start | End | | |
| **Basal Ration 1, Experiment 1** | | | | | | |
| | | | *grams* | | | |
| Check | 12 | 0 | 39 | .... | .... | .... |
| Corn 1.25%[d] | 12 | 2 | 39 | 164 | .... | 2 |
| Vitamin A, 20 I. U. | 12 | 3 | 39 | 213 | .... | 1 |
| Corn, 2.5%[e] | 12 | 8 | 39 | 222 | 2.87 | 8 |
| Vitamin A,40 I. U. | 12 | 8 | 39 | 238 | 2.78 | 1 |
| Corn, 5.0% | 12 | 8 | 39 | 253 | 2.72 | 1 |
| Vitamin A, 80 I. U. | 12 | 10 | 39 | 230 | 2.51 | 0 |
| Corn, 10.0% | 12 | 10 | 39 | 238 | 2.69 | 0 |
| **Basal Ration 2, Experiment 2** | | | | | | |
| Check | 12 | 2 | 39 | 153 | .... | 2 |
| Corn, 1.0% | 12 | 7 | 39 | 285 | .... | 7 |
| Vitamin A, 25 I. U. | 12 | 8 | 39 | 320 | .... | 6 |
| Corn, 2.0% | 12 | 7 | 39 | 305 | .... | 3 |
| Vitamin, A, 50 I. U. | 12 | 12 | 39 | 382 | 2.21 | 2 |
| Corn, 4% | 12 | 12 | 39 | 343 | 2.47 | 3 |
| Vitamin A, 100 I. U. | 12 | 12 | 39 | 394 | 2.14 | 0 |
| Corn, 8% | 12 | 12 | 39 | 375 | 2.51 | 0 |

[d] Tiquisate Golden Yellow (TGY), substituted for the ground sorghum or white corn of the basal diets.
[e] U. S. P. vitamin A standard, added to each 100 g. of the basal diet.
[f] Grams fed to produce one gram of gain.

In Mexico, Central America, Panama, and many areas of South America, human diets are such that it is of the utmost importance that corns with good nutritional value as well as superior agronomic qualities be produced. In Guatemala the rural population depends upon corn for their principal food and consumes quantities as large as 500 g. of corn per person per day *(8)*. Where yellow corn is used, its vitamin A activity is of concern since the most common human vitamin deficiency appears to be that of vitamin A *(8)*.

It seems apparent from this preliminary work that those yellow corns reported to be superior in other qualities *(1, 2, 5)* should be screened by either chemical or biological techniques for their vitamin A activity. Such analyses are also necessary for the correct evaluation of dietary surveys in areas where yellow corn is an important part of the diet.


## SUMMARY

The $\beta$-carotene content of 32 different Guatemalan corns *(Zea mays)* from 2 general areas was determined. In the Antigua area, 13 yellow varieties averaged 0.115 (s 0.062) and 11 white varieties averaged 0.033 (s 0.024) mg. $\beta$-carotene per 100 g. In the Santa Maria Cauque area 4 yellow to red varieties averaged 0.157 and 4 white to black varieties averaged 0.014 mg. $\beta$-carotene per 100 g.

One lowland variety, Tiquisate Golden Yellow (TGY), grown in 4 lowland locations (100-200 feet) averaged 0.330 mg. $\beta$-carotene per 100 g. and when grown in one highland area (approximately 5,000 feet) averaged 0.180 mg. $\beta$-carotene per 100 g.

The vitamin A activity of 2 samples of TGY grown in the lowlands was estimated by chick growth assay to be 0.50 and 0.62 mg. per 100 g. Since the $\beta$-carotene content accounts for less than half of this activity, it is apparent that the analysis of corn for $\beta$-carotene alone is not a satisfactory means of appraising its pro-vitamin A content. Evidence is presented that most of the activity not accounted for by $\beta$-carotene is due to cryptoxanthol.



### Acknowledgment

The authors desire to express their appreciation to S. Pizzati, R. Oro, M. Monzón and G. Arroyave for their technical assistance in this work.


## LITERATURE CITED


1. Aguirre, F., Robles, C. E., and Scrimshaw, N. S. The nutritive value of Central American Corns. II. Lysine and methionine content of twenty-three varieties in Guatemala. *Food Research*, 18, 268 (1953).
2. Aguirre, F., Bressani, R., and Scrimshaw, N. S. The nutritive value of Central American Corns. III. Tryptophane, niacin, thiamine, and riboflavin content of twenty-three varieties in Guatemala. *Food Research*, 18, 273 (1953).
3. Aurand, L. W., Miller, R. C., and Huber, L. L. The influence of heredity on the carotene content of corn. *Science*, 106, 493 (1947).
4. Aurand, L. W., Miller, R. C., and Huber, L. L. Influence of heredity on carotene and protein contents of corn. The Pennsylvania State College, Agr. Expt. Sta. State Coll. *Bull. 526* (1950).
5. Bressani, R., Arroyave, G., and Scrimshaw, N. S. The nutritive value of Central American corns. I. Nitrogen, ether extract, crude fiber, and minerals of twenty-four varieties in Guatemala. *Food Research*, 18, 261 (1953).
6. Guilbert, H. R. Determination of carotene as a means of estimating the vitamin A value of forage. *Ind. Eng. Chem., Anal. Ed.*, 6, 452 (1934).
7. Guzmán, M., and Scrimshaw, N. S. Serum ascorbic acid, vitamin A, carotene, vitamin E, riboflavin, and alkaline phosphatase values in Central American school children. *Fed. Proc.*, 11, 445 (1952).
8. Instituto de Nutrición de Centro América y Panamá. (Unpublished data.)
9. Kemmerer, A. R., Fraps, G. S., and Mangelsdorf, P. C. The relation between the vitamin A active carotenoids in corn and the number of genes for yellow color. *Cereal Chem.*, 19, 525 (1942).
10. Mangelsdorf, P. C., and Fraps, G. S. A direct quantitative relationship between vitamin A in corn and the number of genes for yellow pigmentation. *Science*, 13, 241 (1931).

11. PETERSON, W. J., HUGHES, J. S., AND FREEMAN, H. F. Determination of carotene in forage. A modification of the Guilbert method. *Ind. Eng. Chem., Anal. Ed.*, 9, 71 (1937).

12. QUACKENBUSH, F. W. (Personal communication, 1949).

13. RANDOLPH, L. F., AND HAND, D. B. Relation between carotenoid content and number of genes per cell in diploid and tetraploid corn. *J. Agr. Research*, 60, 51 (1940).

14. SADANA, J. C., AND AHMAD, B. The carotenoid pigments of local varieties of yellow maize. *Indian J. Med. Research*, 34, 59 (1946).

15. SCOTT, G. C., AND BELKENGREN, R. O. Importance of breeding peas and corn for nutritional quality. *Food Research*, 9, 371 (1944).

16. WHITE, J. W., BRUNSON, A. M., AND ZSCHEILE, F. P. Studies on the carotenoids. V. Spectrophotometric determination of the carotenoids of yellow corn grain. *Ind. Eng. Chem., Anal. Ed.*, 14, 778 (1942).