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NUTRITIVE VALUE OF CENTRAL AMERICAN CORNS V. CAROTENE CONTENT AND VITAMIN A ACTIVITY OF THREE GUATEMALAN YELLOW CORNS

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In Central America corn is used extensively in animal feeds and may make up as high as 75% of human diets in rural areas. Avitaminosis A is a major nutritional problem of both humans and animals and estimation of vitamin A activity of feedstuffs is important. Bressani *et al. (4)* have shown that for this estimation, chemical methods must consider both cryptoxanthin and beta-carotene since local yellow corns contain significant amounts of both pigments.

In the present report further data are presented on the beta-carotene and cryptoxanthin content of three Guatemalan yellow corns and their vitamin A activity as shown by chemical determinations, as well as the growth, mortality, and blood serum levels of vitamin A and carotene of baby chicks.

MATERIALS AND METHODS

The characteristics of the three Guatemalan yellow corns, Tiquisate Golden Yellow (TGY), 142-48 and Santa María Cauqué (SMC), have been previously described *(3)*. Total carotenoid pigments were extracted with petroleum ether and then washed with 90% aqueous methanol to remove lutein and zeoxanthin. The carotenoid extract was first read at 440 mμ[c] and then passed through a magnesium oxide-celite column. The beta-carotene was eluted with 5% acetone in petroleum ether according to the method of Guilbert *(5)* as modified by Peterson *et al. (6)*, and the cryptoxanthin remaining in the column was eluted with 15% acetone in petroleum ether. Both fractions were read at 440 mμ. An absorption curve of the latter fraction was identical with that of cryptoxanthin. Total vitamin A activity was calculated on the basis of cryptoxanthin having one-fourth, and beta-carotene one-half, the activity of crystalline vitamin A.

For the biological trials, 3-day-old New Hampshire baby chicks were distributed by weight among 16 experimental groups. Each group contained 12 chicks and was housed in an all-wire cage with the temperature decreased progressively from 35° C. at 3 days to 21° C. at 5 weeks. The birds were weighed weekly during a 35-day period; the diets and water were fed *ad libitum* and feed consumption recorded daily.

The composition of the low vitamin A basal ration in grams per 100 grams was: sesame oil meal, 30; corozo oil meal,[d] 15; vitamin test casein, 4; ground sorghum, 47;

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[c] Evelyn colorimeter.

[d] This is prepared from the nut of the palm *Orbignya cohume*.

mineral mixture with minor elements,[e] 3; APF,[f] 0.7; Delsterol, 0.02; and 0.5 ml. of an aqueous vitamin B-complex solution. Each corn was fed at 1, 3, 6, and 12% of the basal ration replacing part of the ground sorghum. The control rations contained 0, 30, 60, and 120 I. U. of vitamin A, added to each 100 grams of the basal ration.

At the end of the 5-week feeding period, each bird was bled by heart puncture and the blood samples refrigerated and centrifuged one hour later. The individual serum samples were analyzed for total carotenoids and vitamin A by the method of Bessey *et al. (2)*.

RESULTS

Total carotenoid, beta-carotene and cryptoxanthin of the 3 corn samples are given in Table 1, together with the calculated vitamin A activity. Total carotenoids were

TABLE 1

Total carotene, beta-carotene and cryptoxanthin content of three Guatemalan corns

Corn	Total carotene	Beta-carotene		Cryptoxanthin		Estimated vitamin A activity [1]
	mcg./g.	mcg./g.	% of total	mcg./g.	% of total	mcg./g.
TGY	11.28	3.00	26.5	4.33	38.3	2.58
142-48	8.87	1.95	21.9	5.04	56.8	2.24
SMC	6.37	1.22	19.2	3.65	57.3	1.52

[1] ½ beta-carotene + ¼ cryptoxanthin.

highest in the variety TGY (11.28 mcg./g.) and significantly lower in 142-48 (8.87 mcg./g.) and SMC (6.37 mcg./g.). The beta-carotene of TGY was 35% higher than that of 142-48 and 59% higher than that of SMC. However, variety 142-48 had the largest amount of cryptoxanthin (5.04 mcg./g.) with TGY (4.33 mcg./g.) next and SMC (3.65 mcg./g.) the lowest.

Weight in grams, efficiency of feed utilization and mortality of the chicks fed the various levels of the 3 corns are shown in Table 2. One hundred per cent mortality from avitaminosis A occurred in the chicks fed the unsupplemented basal ration. Sixty or more I. U. of vitamin A or 3% or more of each of the corns tested proved sufficient to prevent death from avitaminosis A under the conditions of the trial.

Rate of growth and efficiency of feed utilization were highest in the groups fed 142-48, with those fed SMC intermediate, and TGY the lowest. The growth rates of the chicks fed the control ration containing 30, 60, and 120 I. U. of vitamin A were similar to those of chicks fed the 6 and 12% levels of the corn varieties 142-48 and SMC and at all levels superior to the growth of the chicks fed TGY.

Data in Table 3 indicate that the blood serum carotenoids and vitamin A levels were significantly higher in the groups fed TGY than 142-48 and SMC. The blood serum, vitamin A, and carotene levels of the chicks fed the different corns showed a highly significant linear relationship to the various levels of carotene ($Y = 0.05X + 24.7$) and vitamin A ($Y = 0.004X + 0.20$) fed (Figure 1). The 900 mcg. standard fell exactly on the serum vitamin A regression line and that for 1800 and 3600 mcg. below it. The carotene vitamin A ratio was similar in the groups fed 142-48 and SMC and approximately twice as high in the groups fed TGY.

DISCUSSION

By calculation the chemical data indicate that all three of the varieties of yellow corn should contain sufficient vitamin A activity for the physical

[e] This mixture consisted of one part calcium carbonate, one part sodium chloride, one part bonemeal and one-tenth part of the minor element mixture "Mini-Rich" produced by the Thompson-Hayward Chemical Company.

[f] Aureofac, courtesy of Dr. T. H. Jukes and the Lederle Laboratories, N. Y.

TABLE 2
Vitamin A activity, growth, mortality, feed efficiency data and vitamin A and total carotene levels in blood serum

Ration	No. chicks at end [1]	Final weight grams	Efficiency feed utilization
Control (Amount of vitamin A)			
0 mcg. (0 units)	0	—	—
900 mcg. (30 units)	11	323	2.66
1800 mcg. (60 units)	12	377	2.20
3600 mcg. (120 units)	12	367	2.26
Corn TGY (Proportion fed)			
1%	10	229	3.50
3%	12	257	2.98
6%	12	304	2.84
12%	12	295	2.86
Corn 142-48			
1%	9	269	3.30
3%	12	294	2.44
6%	12	318	2.32
12%	11	381	2.30
Corn SMC			
1%	8	257	4.22
3%	12	281	2.62
6%	12	324	2.54
12%	12	347	2.45

[1] All groups began with 12 chicks.

well-being of baby chicks. However, the vitamin A activity is contributed largely by cryptoxanthin and beta-carotene and the relative amounts of each are not constant among different corns. This further emphasizes the importance of analyzing corn for both cryptoxanthin and beta-carotene.

The biological assays with chicks showed that when 3% of any of the three corns studied was fed in the basal ration, no mortality occurred. In the case of both 142-48 and SMC the higher the level fed within the range studied, the greater the weight gain and the better the feed efficiency. However, with corn variety TGY the growth and feed efficiency at the highest level fed was actually poorer than at an intermediate level. Although no

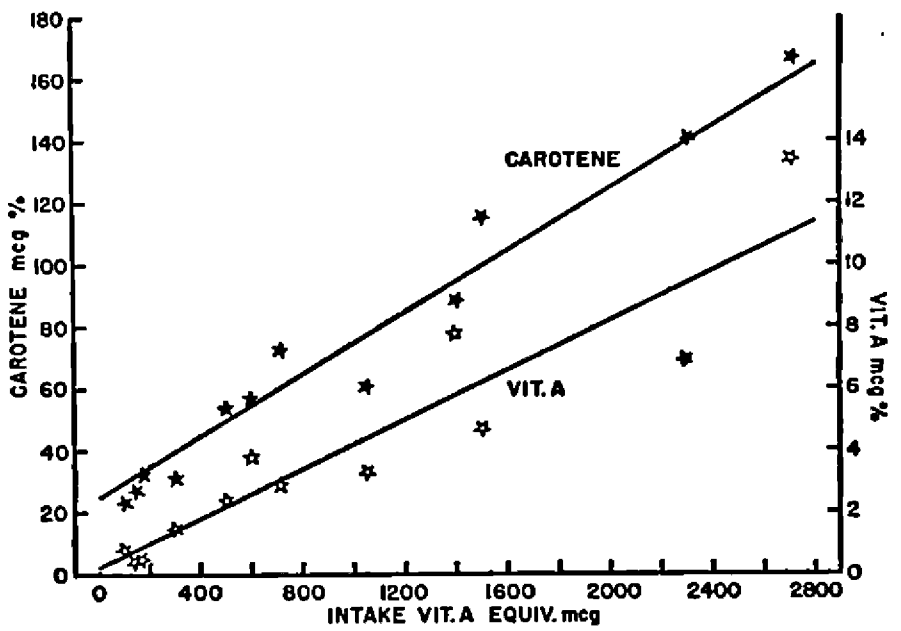

Figure 1. Relationship of vitamin A intake and serum levels of carotene and vitamin A.

TABLE 3
Effect of 3 Guatemalan corns on the blood serum vitamin A and carotene levels of New Hampshire baby chicks

Ration	Dietary Intake				Blood Serum	
	Total carotene	Cryptoxanthin	Beta-carotene	Vitamin A equivalent[1]	Carotene	Vitamin A
%	*mg.*	*mg.*	*mg.*	*mg.*	*mcg./100 ml.*	*mcg./100 ml.*
TGY						
1	0.72	0.27	0.19	0.16	33	0.46
3	2.67	1.01	0.70	0.60	57	3.78
6	6.10	2.34	1.62	1.40	88	7.75
12	11.88	4.56	3.15	2.72	167	13.42
142						
1	0.57	0.32	0.13	0.14	27	0.40
3	1.99	1.13	0.44	0.50	54	2.40
6	4.13	2.35	0.91	1.04	61	3.30
12	9.09	5.17	2.00	2.29	140	6.90
SMC						
1	0.43	0.25	0.08	0.10	23	0.85
3	1.31	0.75	0.25	0.31	31	1.50
6	3.01	1.73	0.58	0.72	73	2.90
12	6.27	3.59	1.20	1.50	116	4.70
Vitamin A (Standard)						
0 I.U.	.....	.....	.....	0.00	....	.....
30 I.U.	.....	.....	.....	0.90	28	3.80
60 I.U.	.....	.....	.....	1.80	25	5.50
120 I.U.	.....	.....	.....	3.60	23	10.20

[1] ½ beta carotene + ¼ cryptoxanthin

certain explanation can be given for this depression of growth in chicks fed the highest level of TGY in this particular trial, it is possible that it was due to treatment with Arasan[g] which this sample alone received. Ackerson and Mussehl *(1)* have reported growth depression in chicks fed corn treated with either Arasan or Orthocide and Waibel, Pomeroy and Johnson *(9)* have shown that Arasan-treated corn had a very pronounced depressing effect on egg production. The data for TGY are included because, despite the comparatively poorer growth rate, the serum vitamin A and carotene levels show the same highly significant linear trend with the amount of corn fed as observed for the other two varieties.

The data for all three corns show excellent agreement between their carotene content, calculated for vitamin A activity, and the blood serum levels of vitamin A and total carotene. The corn with the highest estimated vitamin A activity, TGY, maintained the highest serum carotene and vitamin A at each level fed. Moreover, the ratio of vitamin A to carotene in the blood of chicks fed TGY was almost twice that of those given 142-48 or SMC, suggesting a higher efficiency of conversion.

The relationship between the amount of corn fed and the resulting levels of vitamin A and carotene was such that the vitamin A activity of corn could be estimated from blood levels alone if suitable standards were run simultaneously. In this connection it should be noted that the first standard fell exactly on the calculated line for the vitamin A activity of the cereal meals determined by chemical analysis and that the intercept of this line

was essentially zero. The two higher standards fell somewhat below the calculated line suggesting that at higher dosage levels the vitamin A standard was less efficiently absorbed than the carotene in the corns.

The intercept of 24.7 mcg. for the serum carotene regression line was close to the lower limit of serum carotene observed in previous depletion experiments *(7, 8)*. It is useful to call attention again to the inadequacy of estimating vitamin A activity of many plants from the determination of a single carotene such as beta-carotene or cryptoxanthin. Accurate chemical estimations of vitamin A activity require the analysis of all of the active carotenes which may be present along with the assigning of a proper factor for their relative activity.

SUMMARY

Three varieties of yellow corn grown in Guatemala were found by chemical analysis to have the following vitamin A activity: TGY 2.58 mcg./g.; 142-48, 2.24 mcg./g.; and SMC, 1.52 mcg./g. Of this activity, 38.3, 56.8 and 57.3% respectively, was accounted for by cryptoxanthin and the remainder by beta-carotene. Other carotene pigments made up 35.2, 21.3 and 23.5%, respectively, of the total carotene measured. Three per cent of these varieties added to the basal vitamin A deficient ration of baby chicks sufficed to prevent mortality and improve growth. Within the range of 0 to 12% studied blood serum carotene and vitamin A values increased linearly with the amount of corn fed. Highest absolute blood levels and the highest ratio of carotene to vitamin A in the serum were observed for corn variety TGY. The importance of analyzing corn for both beta-carotene and cryptoxanthin is emphasized.

[g] Fungicide for disinfection of seeds produced by Du Pont de Nemours and Company.

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