CAROTENOID, OIL, AND TOCOPHEROL CONTENT OF CORN INBREDS[1]

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ABSTRACT

Analyses of 125 inbreds which are well known to corn breeders in the Midwest showed wide ranges in carotenoid and tocopherol composition. Each inbred showed its own characteristic distribution of the eleven carotenoid fractions for which analyses were made. Provitamin A, calculated from the biologically active pigments as beta-carotene equivalency, ranged from a trace to 7.3 γ per g. of corn. Lutein, the preponderant xanthophyll component, ranged from 2 to 33 γ per g.

Total oil content ranged from 1.2 to 5.7% among the inbreds. The range of estimated iodine values was 111 to 151, and of total tocopherols 0.03 to 0.33% of the oil. There was no apparent correlation between provitamin A content and the percentage or composition of the oil. The quality as well as the yield of the nation's corn crop is evidently quite dependent upon the inbreds selected as parents.

While it is widely recognized that hybrid corn has greatly increased our potential food supply, the belief is not uncommon that it has also resulted in a lowering of the nutritive value of the present-day crop. Webster *et al.* (11) reported that both protein and carotene were found to be significantly lower in hybrid corn than in open-pollinated corn. Bosticco (2) reported that beta-carotene and cryptoxanthin in Italian hybrids were lower than in varieties.

Both oil and yellow pigment are known to be heritable qualities in corn (6,12). That inbreds high in crude carotene also tend to produce progeny which is high in carotene was shown by Aurand

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et al. (1) in studies with ten inbreds which were crossed in all possible combinations.

In view of the reliance which is placed on yellow corn to provide our animal population with fat-soluble nutrients, especially provitamin A, the tocopherols (vitamin E) and the essential fatty acids, it seems important that corn breeders have access to information concerning the amounts of these components in our common inbreds. This paper presents data on 125 inbreds which are well known to breeders in the Midwest.

Materials and Methods

The corn inbreds were grown on the Agronomy Farm at Lafayette during the summer of 1958. The ears were dried to approximately 10% moisture at temperatures not exceeding 45°C. in a forced-air oven. Two to six self-pollinated ears from each inbred were shelled to make a composite sample which was then refrigerated at 0°C. The sample (usually 110 g.) was ground in a burr-type mill (Labconco) for analysis.

The freshly ground samples were extracted by a rehydration-percolation procedure which has been described elsewhere (10). The lipid extract from 100 g. of ground corn was diluted to 100 ml. with hexane (Skellysolve B), and a 25-ml. portion of this extract was used for chromatography to separate the carotenoids. A second 5-ml. portion was placed in a tared beaker and brought to constant weight in a vacuum oven at 50°C. to determine the oil percentage in the corn. The remaining lipid extract was placed in a round-bottom flask and the solvent was removed on a rotary evaporator, the water bath not exceeding 40°C. The resulting oil was placed in a centrifuge tube and refrigerated at −25°C. For the tocopherol determination and the refractive index measurement, this sample was brought to room temperature and mixed thoroughly, then centrifuged. Tocopherols were distilled from the oil as follows: a 1-g. sample was weighed (by difference) into a small pot-type all-glass still assembly in which six pots, 3 cm. in diameter, were fused to a circular tube bearing a standard-taper joint. The assembly could be connected to a high-vacuum source to permit six samples to be molecularly distilled simultaneously. After partial degassing to minimize foaming, the multiple-still assembly was connected to an oil-diffusion pump and the pressure reduced to well below 1μ. The pots were then immersed in an oil bath (175°C.) and distillation was allowed to proceed for 1 hr. These conditions have been shown to give good recovery of synthetic DL-α-tocopherol when added to fresh corn oil or to a stripped residue oil. The distillate was

washed from the condenser with ethanol and analyzed for total tocopherol by the Emmerie-Engel procedure (5). Analyses of eight different 1-g. portions of a sample of corn oil on eight different days over a period of several weeks showed a coefficient of variation of 7%.

Iodine values were not determined directly, but were estimated from refractive index values. The graph of iodine value versus refractive index which was employed had been prepared from analyses of corn which had been grown in the same location during the same season. Experience has shown that this procedure provides good approximations of the iodine values from refractive index data (7).

Results and Discussion

Since the emphasis in this study was mainly on the composition of the carotenoid fraction, the inbreds have been listed in the order of decreasing provitamin A content (Table I). The provitamin A was calculated as beta-carotene equivalent in γ per g. by adding the value for beta-carotene to one-third of the value for beta-zeacarotene (8) and one-half of the value for cryptoxanthin. They were expressed as beta-carotene equivalent rather than international units of vitamin A because of the wide variations which are observed in the efficiency of conversion of beta-carotene to vitamin A by animals on different diets in the different laboratories. In bioassays with rats in our laboratory the conversion is almost quantitative (4,8).

Provitamin A content varied widely among the different yellow inbreds, from a mere trace to 7.3 γ per g. (column 5, Table I). The "white" inbreds (last 16 entries in Table I) contained no measurable quantity. Beta-carotene roughly paralleled the provitamin A content and proved to be the main provitamin A source in most of the inbreds, despite textbook statements that cryptoxanthin is the chief source of vitamin A activity in yellow corn. Beta-zeacarotene, which was only recently recognized as a provitamin A source, was quite variable in the higher provitamin A inbreds, but, in general, it followed beta-carotene and cryptoxanthin in the lower ones.

The xanthophyll pigments, which have been the subject of increasing interest, particularly as pigmenting agents in the poultry industry, also showed wide variations. In general, lutein was preponderant over zeaxanthin as well as over all of the other pigments found in the inbreds. Its range was broad, from 2 to 33 γ per g. of corn. The portion of these xanthophylls esterified with fatty acids (fraction 4) was a small and variable part of the whole. Zeinoxanthin, the biologically inactive monohydroxy alpha-carotene (9), varied from a trace to

7.8 γ per g. The total xanthophyll fraction bore no close relation to total provitamin A content.

The acyclic polyenes, phytoene, phytofluene, and zeta-carotene, were also found to be common components of corn grain. The phytoene fraction, the most saturated of the colorless, fluorescent polyenes, was as abundant as the predominant pigment, lutein.

Total oil content ranged from 1.2 to 5.7% among the inbreds. The oil also varied in composition: estimated iodine values ranged from 111 to 151; total tocopherols ranged from 0.03 to 0.33% of the oil.

No correlation was seen between the provitamin A content and the percent oil or any of its constituents. In general, unsaturation was inversely correlated with percent oil (7).

Two sources of information are available to provide an indication of the reliability of the data for the individual inbreds. The first of these is derived from a comparison with the results of similar analyses performed on many of the same inbreds grown during the previous year. It is not known to what extent the variations may have been influenced by environmental factors alone. However, based on this comparison, the 5% least significant differences are 1.2 for oil percentage, 13 for iodine value, and 4.2 for lutein. Coefficients of variation in percent are 11 for oil, 3.3 for iodine value, and 11 for lutein. These figures take into account year-to-year variations as well as analytical variation, although the data in Tables I and II are from analyses of corn grown in 1958 only.

The second source of comparative data is the results of pigment analyses of seven inbreds, samples of which were obtained from plant breeders in agricultural experiment stations of ten Midwestern states. These samples were grown and selfed in a single plot at Lafayette in the 1959 season. Analytical data on the resulting crop are presented for beta-carotene, for lutein, and for the sum of all pigments (Table III). The results show remarkably good reproducibility for a given inbred, both between breeder's samples and between years for the Purdue seed stocks. It is evident that the amount and distribution of the pigments are quite constant for an inbred carried through successive generations in the hands of the different breeders. Each inbred appears to have its own characteristic amounts of the different carotenoids.

In view of the wide quantitative differences in carotenoids between the different inbreds, it is of interest to know the pattern of inheritance in single and double crosses therefrom. Data from other experiments (3) have shown that single-cross hybrids between high-carotene and low-carotene lines are intermediate in composition, with little

TABLE I

CAROTENOID, OIL, AND TOCOPHEROL CONTENT OF CORN INBREDS

INBRED	OIL	IODINE VALUE [a]	TOTAL TOCOPHEROLS	CALC'D PROVITAMIN A [b]	TOTAL PIGMENT [c]
	%		% in oil	γ/g.	γ/g.
Oh45	4.6	137	0.19	7.3	57.9
Oh26A	5.7	129	.11	7.2	53.8
Oh26	4.1	129	.18	6.6	44.3
B38	4.4	126	.11	6.6	45.6
Mo[3]=Mo 0221	3.2	134	.12	6.3	24.8
Tr^{T}Rf	3.0	144	.11	6.2	35.0
A25	2.8	... [d]	.. [d]	6.1	47.6
H54	3.7	117	.12	6.0	26.1
H50	4.9	120	.21	5.8	45.1
Kys	4.9	114	.13	5.8	54.0
B37	4.1	124	.12	5.7	53.0
J553	4.5	122	.13	5.5	37.3
A71	4.9	127	.07	5.2	34.0
K4	4.7	122	.15	5.1	23.2
Oh43	4.2	131	.22	5.0	48.5
W8-A	3.6	139	.18	5.0	43.6
L304A^{T}Rf	5.0	120	.10	4.8	31.0
Oh480	4.1	118	.09	4.5	50.8
Oh28	3.1	134	.12	4.4	43.2
J554	4.0	129	.14	4.4	40.3
B21	4.7	131	.17	4.4	45.2
N6	5.0	122	.20	4.3	26.7
H41	3.5	140	.10	4.3	49.0
Os420^{T}Rf	3.8	136	.18	4.3	30.0
Ky126	3.9	133	.14	4.2	50.2
A430	4.4	126	.06	4.1	24.1
K720	4.1	131	.18	4.0	36.8
A239	3.7	129	.23	4.0	40.0
O7B	4.5	113	.15	4.0	37.5
L289	3.4	130	0.27	2.6	14.8
Hy^{T}Rf	3.2	145	.18	2.6	23.0
M14^{T}Rf	4.2	124	.07	2.6	30.0
R101	3.1	113	.07	2.2	23.6
Mo2	5.0	120	.18	2.2	24.3
CI31A	5.1	110	.11	2.2	19.9
W56	3.9	126	.22	2.2	21.9
A223	3.6	136	.31	2.2	31.3
H49	3.6	129	.19	2.2	27.0
H71	2.8	125	.10	2.2	16.2
CI42A	3.6	132	.20	2.1	19.1
Mo940	3.5	137	.20	2.0	24.0
H59	3.2	126	.19	1.9	22.3
H14	4.4	118	.11	1.8	17.4
C103^{T}Rf	3.6	118	.08	1.8	30.2
R168	3.4	136	.13	1.8	22.8
B41	4.5	122	.14	1.8	21.9
187-2	4.5	134	.15	1.8	25.2
H45	2.6	129	.22	1.8	30.6
C103	3.7	115	.08	1.8	28.6
L317^{T}Rf	3.4	128	.14	1.8	19.5
CI32	3.7	124	.19	1.7	14.9
W64A	3.8	138	.22	1.7	24.3
N25	3.6	128	.05	1.7	24.1
J557	4.7	125	.08	1.5	15.5
A297	4.4	125	.12	1.5	21.1
B40	2.8	129	.17	1.5	15.6
B2	4.4	128	.14	1.4	22.3
H57	3.7	126	.13	1.3	17.4

J552	4.0	137	.16	3.9	34.6
H61	4.4	125	.10	3.9	25.8
K770	5.6	127	.11	3.9	57.3
Oh28^{T}Rf	3.0	138	.11	3.9	42.7
Oh43E	3.8	137	.29	3.8	37.9
38-11 (NRT)	4.1	121	.22	3.8	38.3
W126	5.3	128	.19	3.8	36.4
MS 213	5.2	116	.15	3.7	34.7
H42	4.2	121	.10	3.6	44.1
B10	4.0	128	.15	3.6	42.4
Os420	4.2	136	.18	3.6	27.0
Ia153	3.5	129	.27	3.6	28.9
H60	3.3	124	.08	3.5	32.2
P8 (NRT)	3.9	122	.06	3.3	26.1
CI38B	5.4	111	.14	3.3	22.1
N610	3.7	122	.14	3.2	25.4
M14 (NRS)	4.4	116	.05	3.2	40.8
O7	4.2	129	.14	3.1	27.9
A545	4.4	120	.11	3.2	29.6
W32	4.0	131	.09	3.0	26.0
Mo1=1864	4.6	123	.17	3.0	28.3
T92	3.4	132	.06	2.9	36.8
Wf9	3.7	129	.15	2.9	31.3
Mo9=1853	3.6	121	.20	2.9	21.3
H46	3.1	115	.21	2.8	31.4
H52	3.8	122	.19	2.8	24.3
B35	4.6	124	.24	2.8	25.0
A257	3.4	135	.24	2.7	36.5
H53	3.7	122	.11	2.7	15.4
MS109	4.5	123	.12	2.7	31.6
Mo3	3.5	130	.29	2.7	37.5
H19	2.9	141	.14	2.7	25.4
CI29A	3.4	134	.18	2.7	30.9
W10	4.3	134	0.10	2.7	35.5
CI317B	4.2	124	.13	1.2	19.1
Oh51	3.9	121	.16	1.2	17.9
Hy-2	2.5	143	.15	1.2	15.0
L317	4.1	118	.15	1.2	15.5
Hy	3.6	138	.20	1.1	18.2
Oh51A	4.7	117	.19	1.1	16.4
B14	3.0	142	.12	1.1	17.6
W22	3.6	132	.10	1.1	21.4
H55	2.9	132	.13	0.9	11.9
H58	3.0	124	.03	0.9	17.7
W22R	3.0	129	.15	0.9	17.4
A295	3.8	114	.25	0.9	18.2
CI28A	4.3	122	.09	0.8	11.6
187-R	3.6	118	.09	0.8	16.4
B9	4.5	114	.08	0.8	11.2
H56	3.2	134	.17	0.7	13.1
Pa86	2.5	128	.09	0.3	5.7
4Co82	3.9	112	.13		0.6
33-16^{T}	3.4	135	.15		0.6
33-16 Fert.	3.3	132	.14		0.4
H21	2.9	134	.08		0.3
H21-5	2.9	126	.08		0.3
H25	4.7	124	.15		0.5
H28	2.7	130	.08		0.8
H29	3.9	121	.12		0.4
H30	3.7	122	.18		0.8
H31	1.2	151	.33		0.5
K41	4.6	124	.15		0.4
K44	3.5	114	.14		0.3
K61	4.3	127	.22		0.9
K64	3.3	118	.14		0.3
K6	2.8	132	.18		0.2
Mo1W	3.9	121	0.23		0.5

[a] Estimated from refractive index values.
[b] Calculated from the biologically active carotenoids and expressed as beta-carotene equivalent.
[c] Sum of all except phytoene and phytofluene.
[d] Insufficient sample.

TABLE II

DISTRIBUTION OF THE CAROTENOIDS

INBRED	FRACTION 1					FRACTIONS					
	Phytoene	Phytofluene	Beta-Carotene	Beta-zea-carotene	Zeta-carotene	2: Zeino-xanthin	3: Crypto-xanthin	4: Esters as Zeaxanthin	5. Lutein	6: Zeaxanthin	7: Polyoxy-pigments
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
Oh45	25.6	9.3	4.4	4.0	4.2	2.2	3.2	4.0	29.2	5.4	1.3
Oh26A	29.2	7.2	3.1	4.7	1.0	2.0	5.1	0.8	17.8	17.6	1.7
Oh26	22.1	6.7	4.3	1.2	0.8	2.5	3.9	0.5	18.2	11.2	1.7
B38	20.9	4.6	4.3	2.6	1.8	3.0	2.8	0.9	25.1	4.3	0.8
Mo[3]=Mo 0221	17.4	4.1	5.0	1.8	1.7	0.4	1.4	4.1	6.8	3.1	0.5
$Tr^{T}Rf$	18.0	5.7	4.7	2.7	2.0	3.7	1.2	0.7	14.0	5.4	0.6
A25	24.0	6.2	4.0	4.6	1.1	7.8	1.1	0.8	23.0	4.1	1.1
H54	14.0	4.5	4.7	0.7	1.4	0.6	2.1	0.3	13.3	1.2	1.8
H50	14.2	5.2	3.8	1.8	0.8	1.1	2.8	1.0	11.1	20.9	1.8
Kys	19.5	5.6	2.4	2.4	1.4	0.8	5.2	1.4	10.1	27.4	2.9
B37	18.4	5.1	3.2	3.2	1.8	1.4	2.7	1.6	28.2	9.1	1.8
J553	17.2	3.7	3.5	2.2	1.5	1.8	2.5	1.0	11.9	12.0	0.9
A71	19.0	4.5	2.7	1.6	1.2	0.5	3.8	1.2	8.2	12.2	2.6
K4	18.2	4.6	3.6	1.2	1.3	0.4	2.2	0.5	7.8	3.1	3.1
Oh43	12.0	4.4	3.2	2.7	2.6	2.0	2.0	1.3	26.9	6.8	1.0
W8-A	8.0	2.6	3.8	0.5	0.5	3.0	2.0	0.6	23.9	7.8	1.5
$L304A^{T}Rf$	13.2	2.9	3.1	1.5	0.6	2.1	2.3	1.0	14.8	4.8	0.8
Oh480	18.6	5.5	2.4	2.6	1.4	2.2	2.4	0.9	28.2	8.5	2.2
Oh28	17.5	3.9	2.7	1.8	0.5	5.9	2.2	0.8	16.9	11.0	1.4
J554	11.9	2.8	2.9	1.8	1.2	1.0	1.7	1.9	21.4	7.8	0.6
B21	21.6	6.5	2.4	2.4	1.4	1.5	2.4	1.3	19.0	13.3	1.5
N6	10.5	2.4	3.0	0.4	0.4	1.1	2.4	0.6	11.9	5.0	1.9
H41	12.0	2.8	3.0	1.0	0.1	3.7	1.9	0.8	28.6	8.3	1.6
$Os420^{T}Rf$	21.2	5.0	3.1	0.8	0.5	2.8	1.8	0.9	12.6	6.6	0.9
Ky126	16.7	3.9	2.5	1.2	1.6	2.6	2.6	0.6	25.3	9.9	3.9
A430	14.0	3.0	3.3	0.4	0.5	2.9	1.5	0.7	11.7	2.7	0.4
K720	12.8	2.8	2.8	0.4	0.9	4.9	2.2	1.0	10.0	13.0	1.6
A239	20.1	5.2	2.3	1.1	1.5	4.3	2.7	1.2	12.6	12.9	1.4
O7B	16.3	4.6	2.6	1.2	1.8	3.2	1.9	1.6	15.7	8.3	1.2
J552	13.7	3.3	2.6	1.6	1.3	4.6	1.3	0.9	13.7	7.9	0.7
H61	24.1	5.5	2.1	1.3	1.0	0.4	2.8	1.9	5.3	8.7	2.3
K770	24.4	6.3	2.1	1.7	1.6	3.6	2.5	1.0	33.1	10.5	1.2
$Oh28^{T}Rf$	16.1	4.0	2.9	0.4	1.0	6.6	1.8	0.9	16.5	11.3	1.3
Oh43E	15.2	3.2	2.2	2.2	1.2	1.3	1.8	0.7	22.0	5.4	1.1

38-11 (NRT)	22.3	6.7	2.8	0.5	1.5	0.7	3.0	1.5	9.4	16.9	2.0
W126	13.2	3.0	1.9	2.5	2.0	0.4	2.1	1.5	14.0	10.7	1.3
MS 213	17.8	7.5	2.5	1.5	1.2	3.2	1.4	0.8	18.0	5.0	1.1
H42	37.8	9.8	1.7	2.5	2.2	2.0	2.2	1.4	22.6	7.2	2.3
B10	18.1	3.9	1.9	1.7	1.8	1.4	2.3	1.1	22.6	8.3	1.3
Os420	21.2	4.8	2.7	0.4	0.9	2.3	1.4	0.8	11.7	6.0	0.8
Ia153	13.5	3.5	1.8	1.4	1.5	0.6	2.6	1.9	10.8	7.4	0.9
H60	15.5	3.8	1.8	0.5	0.3	1.1	3.1	1.1	11.9	11.3	1.1
P8 (NRT)	14.5	2.8	2.0	1.6	1.6	1.4	1.7	1.6	12.2	2.0	2.0
CI38B	24.9	4.2	2.1	0.9	0.4	0.5	1.8	1.2	4.8	9.4	1.0
N610	18.7	4.8	1.7	2.5	2.2	0.8	1.4	0.7	10.0	4.9	1.2
M14 (NRS)	22.0	6.6	1.8	2.2	2.9	2.5	1.3	1.6	18.9	8.0	1.6
O7	11.8	2.7	1.8	1.0	0.8	2.0	2.1	0.8	13.1	5.6	0.7
A545	13.6	3.2	1.2	2.2	1.8	0.5	2.3	1.8	6.1	11.3	2.4
W32	22.0	4.8	1.9	1.2	0.9	1.5	1.5	1.8	10.4	5.2	1.6
Mo1=1864	20.2	4.8	1.4	1.8	2.0	0.7	2.0	0.6	12.1	5.7	2.0
T92	45.8	10.2	1.1	2.4	1.8	1.0	2.0	1.6	18.2	7.3	1.4
Wf9	13.6	4.2	1.4	1.9	1.7	0.8	2.0	1.4	14.8	6.5	0.8
Mo9=1853	13.0	2.6	2.2	0.3	0.7	0.4	1.1	1.0	4.8	9.6	1.2
H46	7.5	3.0	1.3	1.3	1.8	0.8	2.2	1.0	14.3	7.1	1.6
H52	14.5	3.2	1.5	0.7	1.0	1.6	2.1	0.5	12.5	2.8	1.6
B35	20.3	3.2	1.2	1.2	0.7	0.5	2.4	0.8	10.3	6.8	1.1
A257	17.6	5.4	1.2	2.7	2.7	1.2	1.3	1.8	15.8	7.9	1.9
H53	11.0	3.1	1.8	0.7	1.2	1.3	1.5	0.5	6.8	1.0	0.6
MS109	15.0	4.0	1.6	1.5	1.5	1.5	1.1	0.9	18.9	3.9	0.7
Mo3	41.4	10.0	1.4	0.6	1.1	1.1	2.1	1.1	18.8	9.3	2.0
H19	15.7	2.9	1.6	1.2	0.4	1.0	1.2	0.7	14.5	3.7	1.1
CI29A	42.7	9.8	1.0	2.0	2.3	0.6	1.9	1.0	10.5	9.8	1.8
W10	9.6	2.7	1.7	1.3	0.4	2.8	1.0	0.4	19.8	7.2	0.9
L289	10.0	1.7	1.6	0.2	0.5	1.2	1.9	0.3	5.9	1.4	1.8
$Hy^{T}Rf$	12.7	1.6	1.3	0.4	0.2	1.7	2.4	0.7	6.0	9.2	1.1
$M14^{T}Rf$	38.9	9.6	0.7	3.4	2.4	1.1	1.4	1.9	12.8	4.8	1.5
R101	11.6	1.7	1.4	0.2	0.4	0.7	1.5	0.5	13.3	3.7	1.9
Mo2	13.0	3.1	1.1	1.4	1.8	1.1	1.4	0.7	12.2	4.1	0.5
CI31A	12.8	1.8	1.2	0.7	0.5	0.8	1.5	0.3	13.0	0.6	1.3
W56	13.3	2.0	1.4	0.7	0.3	0.6	1.4	0.5	12.5	3.8	0.7
A223	16.8	3.9	2.1	0.3	0.6	3.8	1.3	0.5	16.8	5.2	0.7
H49	14.7	3.1	0.9	2.0	1.4	0.7	1.1	0.9	12.0	7.0	1.0
H71	8.3	1.9	1.4	0.4	0.2	0.7	1.2	0.9	3.7	6.8	0.9
CI42A	14.5	2.0	1.2	0.3	0.2	1.2	1.6	1.4	4.1	7.7	1.4
Mo940	14.6	2.2	1.4	0.0	0.0	1.2	1.4	0.4	14.0	3.0	2.6
H59	13.9	2.3	1.2	0.2	0.7	1.5	1.3	0.4	14.8	0.6	1.6
H14	10.9	1.5	1.1	0.2	0.3	0.1	1.4	1.0	4.2	5.9	3.2

Continued

TABLE II (continued)

DISTRIBUTION OF THE CAROTENOIDS

INBRED	FRACTION 1					FRACTIONS					
	Phytoene	Phytofluene	Beta-Carotene	Beta-zea-carotene	Zeta-carotene	2: Zeino-xanthin	3: Crypto-xanthin	4: Esters as Zeaxanthin	5: Lutein	6: Zeaxanthin	7: Polyoxy-pigments
	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.	γ/g.
C103^{T}Rf	33.0	4.9	0.9	0.2	0.7	0.7	1.7	0.7	12.2	11.8	1.3
R168	14.4	2.1	1.1	0.3	0.2	1.9	1.3	0.5	11.8	4.8	0.9
B41	18.6	5.0	0.7	0.9	1.4	0.2	1.5	0.5	10.3	5.1	1.3
187-2	14.1	3.1	1.0	0.7	0.8	0.4	1.2	0.9	9.4	7.8	3.0
H45	14.8	3.4	1.0	0.4	0.8	1.2	1.3	0.8	17.3	6.6	1.2
C103	24.8	4.2	0.9	0.2	0.7	1.2	1.6	1.1	10.4	11.4	1.1
L317^{T}Rf	11.5	2.8	0.9	0.4	0.6	0.2	1.4	0.4	8.9	5.0	1.7
CI32	13.9	1.9	1.4	0.2	0.2	0.2	0.7	0.4	6.2	4.3	1.3
W64A	14.1	3.3	0.6	1.3	1.4	0.4	1.4	1.7	8.8	7.9	0.8
N25	8.6	1.6	0.8	1.2	0.9	2.2	0.8	0.8	11.3	4.6	1.5
J557	12.2	2.4	0.5	1.2	0.8	0.0	1.1	1.7	2.0	6.6	1.6
A297	17.0	3.3	0.6	1.3	1.4	0.5	0.8	0.6	5.4	9.6	0.9
B40	9.6	0.9	0.7	0.1	0.2	0.6	1.5	0.5	7.1	4.3	0.6
B2	11.4	1.4	0.8	0.3	0.6	0.9	1.0	0.5	12.8	4.2	1.2
H57	16.0	2.7	0.6	0.5	0.6	0.4	1.1	0.6	7.8	4.9	0.9
CI317B	20.6	2.2	0.7	0.3	0.5	0.1	0.8	0.8	4.3	9.2	2.4
Oh51	12.9	2.2	0.5	0.2	0.4	0.6	1.2	0.4	7.6	5.8	1.2
Hy-2	13.6	1.5	0.7	0.2	0.1	1.6	0.9	0.4	6.6	3.9	0.6
L317	9.8	2.2	0.6	0.3	0.5	0.2	1.0	0.4	6.5	4.8	1.2
Hy	10.7	1.3	0.6	0.1	0.2	0.6	1.0	0.5	10.5	3.9	0.8
Oh51A	12.3	1.9	0.5	0.4	0.5	0.4	0.9	0.7	6.5	5.2	1.3
B14	10.0	1.0	0.6	0.2	0.1	1.7	0.7	0.4	9.0	4.0	0.9
W22	13.2	2.3	0.7	0.1	0.5	2.4	0.6	1.1	8.9	6.3	0.8
H55	7.7	1.3	0.5	0.1	0.3	0.5	0.9	0.3	4.1	4.4	0.8
H58	5.6	0.8	0.5	0.1	0.2	0.2	0.8	0.4	8.3	5.4	1.8
W22R	10.8	1.4	0.4	0.2	0.1	0.9	0.9	0.6	10.0	3.7	0.6
A295	7.9	0.9	0.5	0.2	0.2	0.2	0.7	0.4	9.7	5.3	1.0
CI28A	16.2	1.9	0.5	0.1	0.2	0.4	0.6	0.5	7.5	0.6	1.2
187-R	7.7	1.8	0.3	0.8	0.6	0.1	0.4	1.0	6.8	4.5	1.9
B9	12.1	1.2	0.6	0.3	0.2	0.3	0.3	0.3	8.4	0.8	0.0
H56	8.4	1.2	0.4	0.1	0.2	1.5	0.6	1.2	5.6	2.8	0.7
Pa86	11.9	1.5	0.1	0.1	0.1	0.1	0.3	0.4	2.4	1.8	0.4

TABLE III

AVERAGE PIGMENT CONTENT OF CORN OBTAINED FROM DIFFERENT STATES

PEDIGREE	NO. OF STATES	BETA-CAROTENE		LUTEIN		TOTAL PIGMENT	
		γ/g.	std. dev.	γ/g.	std. dev.	γ/g.	std. dev.
Oh45	7	5.4	0.6	31.9	1.3	57.5	2.0
Oh43	7	3.9	0.3	25.1	2.7	45.1	3.6
38-11	5	2.5	0.7	6.3	2.4	31.4	7.1
Wf9	10	1.2	0.2	12.4	1.1	27.0	1.9
N6	6	3.5	0.8	9.4	0.7	24.4	1.4
L317	3	0.7	0.0	5.9	0.2	15.2	0.5
Hy	6	0.8	0.1	4.5	1.8	14.9	1.0
U.S. 13	7	1.3	0.2	7.4	1.7	21.8	1.6

dominance. Data on the double cross, U.S. 13 (WF9 × 38–11) (Hy × L 317) which are presented in Table III indicate a similar pattern. It is of interest that all of the parents of this widely grown hybrid are intermediate or below average in provitamin A content.

Literature Cited

1. AURAND, L. W., MILLER, R. C., and HUBER, L. L. The influence of heredity on the carotene content of corn. Science **106:** 493–494 (1947).
2. BOSTICCO, A. Carotenoid content of corn grains. Changes in the carotene and cryptoxanthine as influenced by the variety and the duration of the vegetative cycle of the plant. Atti. soc. ital. sci. vet. **6:** 174–176 (1952).
3. BRUNSON, A. M., and QUACKENBUSH, F. W. Breeding corn with high provitamin A in the grain. Crop Science **2:** 344–347 (1962).
4. BURNS, M. J., HAUGE, S. M., and QUACKENBUSH, F. W. Utilization of vitamin A and carotene by the rat. I. Effects of tocopherol, tween and dietary fat. Arch. Biochem. **30:** 341 (1951).
5. EMMERIE, A., and ENGEL, C. Colorimetric determination of α-tocopherol (vitamin E). Rec. trav. chim. **57:** 1351–1355 (1938).
6. HAUGE, S. M., and TROST, J. F. An inheritance study of the distribution of vitamin A in maize. III. Vitamin A content in relation to yellow endosperm. J. Biol. Chem. **86:** 167–172 (1930).
7. LOFLAND, H. B., and QUACKENBUSH, F. W. Distribution of fatty acids in corn oil. J. Am. Oil Chemists' Soc. **31:** 412–414 (1954).
8. PETZOLD, E. N., QUACKENBUSH, F. W., and MCQUISTAN, M. Zeacarotenes, new provitamins A from corn. Arch. Biochem. Biophys. **82:** 117–124 (1959).
9. PETZOLD, E. N., and QUACKENBUSH, F. W. Zeinoxanthin, a crystalline carotenol from corn gluten. Arch. Biochem. Biophys. **86:** 163–165 (1959).
10. QUACKENBUSH, F. W., FIRCH, JEAN G., RABOURN, W. J., MCQUISTAN, M., PETZOLD, E. N., and KARGL, T. E. Composition of corn. Analysis of carotenoids in corn grain. J. Agr. Food Chem. **9:** 132–135 (1961).
11. WEBSTER, J. E., BROOKS, J. S., and CROSS, C. B. The protein and crude carotenoid content of hybrid and open-pollenated corn: A summary. Okla Agr. Exp. Sta., Tech. Bull. 36, p. 3 (1949).
12. WOODWORTH, C. N., and MUMM, W. J. Corn breeding shows how oil imports might be replaced. Ill. Agr. Exp. Sta., 47th Annual Rept., pp. 133–134, 48–51 (1935).