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NUTRITIVE VALUE OF CENTRAL AMERICAN CORNS

VI. Varietal and Environmental Influence on the Nitrogen, Essential Amino Acid, and Fat Content of Ten Varieties[1]

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ABSTRACT

Among ten corn varieties planted in Mexico, Guatemala, Nicaragua, and Panama in 1956, average values were: fat, 4.6%; nitrogen, 1.55%; leucine 618, isoleucine 231, valine 236, methionine 119, lysine 172, and tryptophan 26 mg. per g. of nitrogen. Significant locality differences were found in all nutrients assayed except valine. Over-all varietal differences were apparent only in isoleucine, but the presence of a significant locality × variety interaction for all nutrients studied, except fat, suggests that varietal differences may have been present in the different localities. Within-locality analyses confirmed this, indicating varietal differences in the four localities studied.

Tryptophan and lysine, the two most limiting amino acids in corn, showed significant varietal differences at each of the four localities. The estimates of the variance components indicated that selection of varieties based on tryptophan, valine, and lysine content could be successfully undertaken at the local level simultaneously with selection for maximum yield.

Correlations between total nitrogen and each of the amino acids studied were negative, but were significant only with isoleucine, valine, and tryptophan. Valine and tryptophan were positively correlated with isoleucine, lysine, leucine, and methionine, although the coefficients were statistically significant only with the first two.

The importance of corn as a staple food has been repeatedly stressed, since it furnishes up to 64% of the protein in human diets in parts of Mexico and Central and South America (4,8,16). Studies on the nutritive value of corn in Central America have revealed significant differences in protein content and quality among different varieties (1,2,5). Similar results have been reported for corn grown in other areas (9,12,14,15). Assessing the influence of genetic and environmental factors on the amino acid content of corn has nutritional and agricultural importance, since such knowledge could aid in the practical selection of varieties of higher protein quality.

The present study explores the varietal and environmental contribution to the differences in nutrient content of ten varieties of corn.

Materials and Methods

The material utilized in this project was part of a larger study

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carried out by the Institute of Nutrition of Central America and Panama (INCAP) in co-operation with the Rockefeller Foundation and agricultural stations in Mexico, Central America, and Colombia.

Two rows of ten hills with three plants per hill were planted at random in two replications. The yellow and white varieties were in separate plots. Ten fraternal crosses with pooled pollen were made within each variety. Ten ears were sampled at random from each variety, the grain was pooled within varieties, and 400-g. samples were sent to the laboratory for chemical analyses. The ten varieties used in the present study were from the 1956 crop and originated in Veracruz, Mexico; Cuyuta, Guatemala; La Calera, Nicaragua; and Divisa, Panama. Although they differ in latitude, climatic variation was not large since all four localities have in common a low elevation (10–60 meters) and high daylight temperatures with a heavy rainfall, as well as a predominant clay loam soil.

Total nitrogen was determined by the Kjeldahl method using selenious acid and potassium sulfate as catalysts. Moisture and ether extract were determined by standard AOAC methods (3) and the amino acids were assayed microbiologically on acid and alkaline hydrolysates using *Leuconostoc mesenteroides* (6).

Results

The fat and nitrogen content expressed on 14% moisture basis, and the leucine, isoleucine, valine, methionine, lysine, and tryptophan content expressed as mg. of amino acid per g. of nitrogen, are shown in Tables I (Mexico), II (Guatemala), III (Nicaragua), and IV (Panama).

TABLE I

FAT, NITROGEN, AND AMINO ACID CONTENT OF TEN VARIETIES OF MEXICAN CORN[a]

VARIETY	FAT	NITROGEN	LEUCINE	ISOLEUCINE	VALINE	METHIONINE	LYSINE	TRYPTOPHAN
	%	%	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*	*mg/gN*
Rocamex H-503	3.8	1.85	856	186	206	118	170	25
Venezuela-3	4.0	1.41	682	209	277	108	189	34
Amarillo de Cuba	3.9	1.55	531	185	222	136	160	27
Amarillo Salvadoreño	4.7	1.44	722	205	258	139	192	29
Amarillo Tiquizate Dorado	4.5	1.45	691	217	250	151	171	30
Empalizada	3.6	1.54	658	211	255	137	199	32
Sicarigua Mejorada	3.0	1.31	650	226	292	131	175	31
Venezuela-1	4.3	1.63	588	165	206	129	118	26
P.D.(MS) 6	4.1	1.76	663	158	206	109	158	23
Cornelli 54	4.1	1.56	644	184	239	110	153	27
Average	4.0	1.54	673	191	241	123	167	28

[a] Fat and nitrogen expressed on 14% moisture basis.

TABLE II

FAT, NITROGEN, AND AMINO ACID CONTENT OF TEN VARIETIES OF GUATEMALAN CORN[a]

VARIETY	FAT	NITROGEN	LEUCINE	ISOLEUCINE	VALINE	METHIONINE	LYSINE	TRYPTOPHAN
	%	%	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN
Rocamex H-503	3.7	1.60	467	234	240	120	156	23
Venezuela-3	4.7	1.42	550	255	242	134	148	27
Amarillo de Cuba	4.5	1.60	539	204	216	108	132	24
Amarillo Salvadoreño	5.0	1.59	518	211	217	108	144	25
Amarillo Tiquizate Dorado	5.6	1.38	618	250	250	153	167	29
Empalizada	4.1	1.35	638	234	234	128	206	30
Sicarigua Mejorada	6.0	1.32	667	268	275	138	159	34
Venezuela-1	5.1	1.43	587	260	240	107	200	29
P.D.(MS) 6	4.9	1.59	500	217	211	120	133	25
Cornelli-54	4.9	1.47	513	253	227	123	156	27
Average	4.9	1.47	558	234	234	123	162	27

[a] Fat and nitrogen expressed on 14% moisture basis.

TABLE III

FAT, NITROGEN, AND AMINO ACID CONTENT OF TEN VARIETIES OF NICARAGUAN CORN[a]

VARIETY	FAT	NITROGEN	LEUCINE	ISOLEUCINE	VALINE	METHIONINE	LYSINE	TRYPTOPHAN
	%	%	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN
Rocamex H-503	4.3	1.70	461	242	225	101	202	22
Venezuela-3	5.6	1.48	490	252	265	103	213	23
Amarillo de Cuba	6.2	1.65	555	243	254	104	197	24
Amarillo Salvadoreño	4.9	1.68	557	256	250	97	193	25
Amarillo Tiquizate Dorado	5.1	1.70	573	253	230	101	191	22
Empalizada	4.1	1.64	523	250	227	110	209	31
Sicarigua Mejorada	4.0	1.85	418	242	227	93	175	21
Venezuela-1	4.6	1.58	552	279	230	109	206	30
P.D.(MS) 6	4.4	1.68	534	261	222	108	182	23
Cornelli-54	4.6	1.57	463	256	238	116	195	28
Average	4.8	1.65	514	254	237	104	197	25

[a] Fat and nitrogen expressed on 14% moisture basis.

TABLE IV

FAT, NITROGEN, AND AMINO ACID CONTENT OF TEN VARIETIES OF PANAMANIAN CORN[a]

VARIETY	FAT	NITROGEN	LEUCINE	ISOLEUCINE	VALINE	METHIONINE	LYSINE	TRYPTOPHAN
	%	%	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN	mg/gN
Rocamex H-503	4.8	1.58	739	242	242	133	170	22
Venezuela-3	4.7	1.55	765	235	204	123	160	27
Amarillo de Cuba	4.9	1.49	718	237	212	122	141	23
Amarillo Salvadoreño	5.0	1.47	753	266	240	130	162	23
Amarillo Tiquizate Dorado	5.1	1.50	701	229	236	127	134	23
Empalizada	4.5	1.57	768	238	250	122	177	30
Sicarigua Mejorada	4.0	1.55	704	259	247	123	179	23
Venezuela-1	4.5	1.55	691	241	228	130	160	23
P.D.(MS) 6	5.2	1.52	692	245	245	126	176	23
Cornelli-54	5.1	1.51	696	247	228	120	165	20
Average	4.8	1.53	725	244	231	125	163	24

[a] Fat and nitrogen expressed on 14% moisture basis.

Ether Extract. The ether-extractable portion of the ten varieties averaged 4.0, 4.9, 4.8, and 4.8% in Mexico, Guatemala, Nicaragua, and Panama, respectively. Analysis of variance gave no indication of real differences in the fat content among the ten varieties, although it varied significantly with locality. These differences were uniform for the different varieties as indicated by the lack of a significant locality-by-variety interaction.

Total Nitrogen. The nitrogen content of the ten varieties averaged 1.54, 1.47, 1.65, and 1.53% in Mexico, Guatemala, Nicaragua, and Panama, respectively. The analysis of variance showed significant differences in nitrogen content within varieties grown in different localities; the significant locality × variety interaction indicated that the differences in nitrogen content observed between localities were not the same for all varieties.

Although there were indications of varietal differences in nitrogen content which could be explained by differences in moisture content, these failed to reach the 0.05% level of significance. However, in view of the observed differences in nitrogen content, it was considered appropriate to calculate the analysis of variance for the amino acid content of the different varieties on the basis of g. of amino acid per g. of nitrogen. This automatically corrected for differences in both moisture and total nitrogen.

Leucine. The leucine content of the ten varieties averaged 673, 558, 514, and 725 mg. of leucine per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama, respectively. Upon analysis of variance a significant difference in leucine content between localities was apparent, and while there was no evidence of significant differences among the varieties studied, there was a significant locality-and-variety interaction which indicated that locality differences were not uniform for all varieties. In other words, varietal differences in leucine content may have existed within a given locality.

Isoleucine. The isoleucine content of the ten varieties averaged 191, 234, 254, and 244 mg. of isoleucine per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama, respectively. Within-locality analysis indicated varietal differences in the content of isoleucine in the material grown at the experimental station in Mexico. Since the estimate of error from this locality was extremely small and differed significantly from the estimates obtained in the other localities, Mexican data were excluded from the analysis of the combined results from all localities. The analysis of the isoleucine content of the varieties cultivated in the remaining three localities indicated significant differences among localities and varieties but gave no evidence

of a real locality × variety interaction.

Valine. The valine content of the ten varieties averaged 241, 234, 237, and 231 mg. of valine per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama respectively. Statistical analysis showed that there was no evidence of significant differences in valine content attributable to either locality or variety. There was, however, evidence of significant locality × variety interaction.

Methionine. The methionine content of the ten varieties averaged 123, 123, 104, and 125 mg. of methionine per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama, respectively. Upon analysis of variance there was evidence of locality differences in methionine content; the significant locality × variety interaction indicates that varietal differences may have been present in any one locality.

Lysine. The lysine content of the ten varieties averaged 167, 162, 197, and 163 mg. of lysine per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama, respectively. The results of the analysis of variance indicated significant differences between localities for the content of lysine in all varieties. The presence of a significant locality × variety interaction indicated that the differences observed between varieties in a given locality were not uniform for all localities.

Tryptophan. The tryptophan content of the ten varieties averaged 28, 27, 25, and 24 mg. of tryptophan per g. of nitrogen in Mexico, Guatemala, Nicaragua, and Panama, respectively. Upon analysis of variance, evidence of significant differences in tryptophan content was found which may be attributed to locality. In addition, there was evidence of a significant locality × variety interaction. Again this indicated that while real varietal differences may have been evident at any one locality, they were not evident in all localities, since the differences were not constant in either direction or magnitude from locality to locality and may well have tended to cancel one another.

Discussion

Significant differences among localities were evident for all the nutrients studied except valine. Similarly, the locality × variety interaction proved significant for all nutrients with the exception of ether extract and isoleucine. While significant differences among varieties were detectable only in the case of isoleucine, there may exist for other nutrients varietal differences at any given locality which are not uniform for all localities. In fact, within-locality analyses indicated the presence of significant varietal differences as follows: for total nitrogen and leucine content in the plantings at Mexico and Nicaragua; for isoleucine content only in the plantings

TABLE V

VALUES OF ESTIMATED VARIANCE COMPONENTS IN THE NUTRIENTS IN TEN CORN VARIETIES PLANTED IN FOUR LOCALITIES

Nutrient	Interaction		Replications in Localities		Variety		Locality		Experimental Error		Total Absolute
	Absolute	Per Cent	Absolute	Per Cent	Absolute	Per Cent	Absolute	Per Cent	Absolute	Per Cent	
Moisture	0.30998	17	0.00327	0.2	0.04197	2	1.22442	69	0.19203	11	1.77167
Fat	0.10252	15	0.03930	6	0.01594	2	0.10226	15	0.42084	62	0.68086
Nitrogen	0.00615	30	0.00021	1	0.00259	12	0.00539	26	0.00645	31	0.02079
Leucine	0.00322	23	6×10^{-5}	..	.....	..	0.903×10^{-2}	66	0.146×10^{-2}	11	0.01377
Isoleucine	0.10×10^{-3}	25	.....	..	0.2×10^{-4}	5	0.4×10^{-4}	10	0.24×10^{-3}	60	0.00040
Valine	0.32×10^{-3}	62	0.1×10^{-4}	2	0.5×10^{-4}	9	.....	..	0.14×10^{-3}	27	0.00052
Methionine	0.10×10^{-3}	56	0.2×10^{-4}	11	.....	..	.....	..	0.6×10^{-4}	33	0.00018
Lysine	0.28×10^{-3}	39	0.1×10^{-4}	1	0.5×10^{-4}	7	0.25×10^{-3}	36	0.12×10^{-3}	17	0.00071
Tryptophan	0.1×10^{-4}	56	.....	..	0.2×10^{-5}	11	0.4×10^{-5}	22	0.2×10^{-5}	11	0.000018

at Mexico; for valine content in the plantings at Mexico, Guatemala, and Panama; for methionine content in the plantings at Mexico and Guatemala; for lysine and tryptophan content in the plantings at all four localities.

The latter is extremely important, since lysine and tryptophan are the two most deficient amino acids in corn as shown by balance studies in children (7,17). It is possible that varietal differences tend to disappear in the over-all analysis because of the presence of significant locality × variety interactions, since the observed varietal differences in any one locality could compensate for the difference observed in another locality. It is interesting to note also that there is no evidence of significant differences between replicates within localities in this study. It seems apparent, therefore, that *selection of varieties based on nutrient content can and must be undertaken at the local level.* The estimated variance components presented in Table V confirm this.

Within-variety correlations are shown in Table VI for nitrogen content and each amino acid, as well as for amino acid pairs. Any interpretation of the correlations is limited by the relatively small

TABLE VI

WITHIN-VARIETY CORRELATION COEFFICIENTS OF NITROGEN AND AMINO ACIDS IN TEN VARIETIES OF CORN IN FOUR LOCALITIES

	Isoleucine	Leucine	Valine	Lysine	Methionine	Tryptophan	Fat
Nitrogen	−0.654*	−0.068	−0.725*	−0.299	−0.235	−0.824**	−0.232
Isoleucine	.....	−0.058	0.759**	0.370	−0.113	0.690*	.....
Leucine	.....	.....	0.350	0.766**	0.380	0.308	.....
Valine	.....	.....	.....	0.616*	0.113	0.691*	.....
Lysine	.....	.....	.....	.....	−0.050	0.426	.....
Methionine	.....	.....	.....	.....	.....	0.219	.....

ranges of variation observed for some of the amino acids studied. The results suggest that the contents of leucine, lysine, and methionine tend to be negatively but weakly correlated with the total nitrogen content. The correlations for nitrogen-isoleucine, nitrogen-valine, and nitrogen-tryptophan proved significant, and were uniformly negative. Results of a similar nature were reported by Frey (11).

The correlations between amino acid pairs were heterogeneous both in magnitude and direction, and only positive correlations reached significance. These were isoleucine-valine, leucine-lysine, valine-lysine, isoleucine-tryptophan, and valine-tryptophan. Correlation coefficients reported by Frey (11) showed that valine, leucine, and isoleucine were more closely related to one another than to tryptophan in the corn grain. Although there were negative correla-

tions observed in the case of some pairs of amino acids, these were of such small magnitude that they have little meaning. In general, all of the amino acids studied tend to increase together. Hence, *selection should be carried out on an amino acid content basis rather than on a total-nitrogen basis.*

The results of the present study indicate that tryptophan, valine, and isoleucine are the most promising amino acids for this purpose because of the strong correlation of these three amino acids to total nitrogen and to the other essential amino acids. Variability in valine to tryptophan content has a rather high variety component which is approximately equal in magnitude to the variety component of nitrogen content.

It is recognized that, from a practical point of view, selection cannot be made for improved nutritive value unless yield is also satisfactory. The original experimental designs called for the simultaneous collection of yield data, but the information obtained was not sufficiently complete to permit analyses of the results in terms of yield. Future studies will correct this involuntary omission.

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