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THE NUTRITIVE VALUE OF CENTRAL AMERICAN CORNS. I. NITROGEN, ETHER EXTRACT, CRUDE FIBER, AND MINERALS OF TWENTY-FOUR VARIETIES IN GUATEMALA[a]

RICARDO BRESSANI, GUILLERMO ARROYAVE
Instituto de Nutrición de Centro América y Panamá (INCAP)

AND

NEVIN S. SCRIMSHAW
Nutrition Section, Pan American Sanitary Bureau and INCAP

Guatemala, Central America

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Corn (Zea mays) is the most important constituent of rural diets in Central America. In some indigenous families of the Guatemalan highlands it furnishes 80% of the calories and 70% of the protein *(14)*. Any change favorable or unfavorable in the nutritive value of local corn, and particularly in the quantity and quality of its protein will have far reaching effects in human nutrition in this area. Yet comparatively little is known about the range of variability in the content of essential nutrients that exists in the numerous varieties, races, and strains of corn consumed by the people.

Agricultural stations in Central America are at present attempting to develop higher yielding and more disease and drought resistant corns. Unfortunately there appears to be a tendency for such corns to have lower contents of important nutrients *(2)*. By including the most important of these nutrients in hybridization and selection efforts *(3, 4, 5, 11, 21, 23, 25)*, as well as by soil fertilization *(24)* and good soil management *(6, 27, 28)*, significant improvements in nutritive value can be obtained. When valuable genes associated with desirable nutritive qualities are lost through breeding for yield and resistance alone, as seems to have been done in the United States and elsewhere for many years, the task of improvement may be more difficult.

It was expected that the great diversity of corns cultivated in Central America must include some with more desirable nutritional characteristics than those in common use. If varieties of corn superior in nutritive value for each region could be found equal or superior in yield to those already in wide use, they could be increased and distributed as seed to effect an immediate improvement. Moreover, such corns could be further improved in nutritive value as well as yield through breeding *(8, 9)*. Such improvement could constitute an important contribution to the people directly dependent on a high corn diet.

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[a]A cooperative study in which 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-22 from the Instituto de Nutrición de Centro América y Panamá.

This series of papers reports the biochemical studies carried out as part of such an improvement program. The first four describe the analysis of a group of representative corns selected to test the validity of this approach and to constitute plant material for a corn breeding program. The present paper is concerned primarily with the nitrogen content of these corns, although their moisture, crude fiber, ether extractable fraction, and minerals are also described. Subsequent papers concerning these corns will report their contents of (a) lysine and methionine; (b) tryptophane, niacin, thiamine, and riboflavin; (c) carotene. Studies of genetic and environmental influences on the nutritive value of specific corns are also in progress.

MATERIALS AND METHODS

The origin of each of the 24 varieties of corn studied is listed in Table 1. All were in common use in the region indicated. These corns were the most promising varieties found among over 400 grown in variety trials in 2 climatic zones, Antigua and Tiquisate. The varieties low in yield and quality of grain were eliminated in these trials.

The 2 Mexican corns were found growing in the vicinity of the villages named. The Venezuelan variety was developed at one of the Venezuelan Experiment Stations and distributed to corn growers. The variety TGY was a selection from a cross between two Cuban varieties. The variety 142–48 was a selection from the variety cross TGY and

TABLE 1

Some information concerning the twenty-four varieties of Latin American corns

Variety no.	Town	State or department	Altitude	Color	Group	Country	Year grown
			feet				
206-44⊗	Quezaltenango	Quezaltenango	7,500	W	Mountain	Guatemala	1949
159-44 # (2s)	Chichi.	El Quiché	6,800	Y	Mountain	Guatemala	1949
47A–46 O.P.	Cobán	Alta Verapaz	4,200	W	Giganteum	Guatemala	1948
1470–45 #	San Sebastián	Huehuetenango	6,000	W	Giganteum	Guatemala	1948
25A–46⊗	Chichi.	El Quiché	5,200	Y	Giganteum	Guatemala	1948
92A–46 # ⊗	Paraje Nuevo	Veracruz	....	Y	Giganteum	Mexico	1948
192–44 # ⊗	....	....	....	Y	Giganteum	Guatemala	1948
15A–46 O.P.	Villa Nueva	Guatemala	4,855	Y	Giganteum	Guatemala	1949
166–44 O.P.	Los Pinos	Mexico	....	W	Giganteum	Mexico	1949
31–44 #	Antigua	Sacatepéquez	5,000	Y	Giganteum	Guatemala	1949
20–47⊗	Mixco	Guatemala	5,000	Y	Giganteum	Guatemala	1949
1483–45⊗	Aguacatán	Huehuetenango	5,128	W	Giganteum	Guatemala	1949
21A–46B #	LaDemocracia	Escuintla	380	W	Coast	Guatemala	1947
10A–46 O.P.	Chocolá	Suchitepéquez	2,700	Y	Coast	Guatemala	1948
142–48 O.P.	Tiquisate	Escuintla	150	Y	Coast	Guatemala	1948
118A–46 #	Guatemala	Guatemala	4,855	W	Coast	Guatemala	1948
92–44 O.P.	Retalhuleu	Retalhuleu	300	W	Coast	Guatemala	1948
129A–46 #	....	....	....	Y	Coast	Venezuela	1948
12A–46 # ⊗	Chocolá	Suchitepéquez	2,700	Y	Coast	Guatemala	1948
TGY	Tiquisate	Escuintla	150	Y	Coast	Guatemala	1949
1626–45 O.P.	Chocolá	Suchitepéquez	2,700	W	Coast	Guatemala	1949
7A (WF9x38–11)	Antigua	Sacatepéquez	4,953	Y	Hybrid	Guatemala	1948
26A–46⊗	Sanarate	Progreso	2,632	W	Early Dwarf	Guatemala	1949
200–47 O.P.	Patzún	Chimaltenango	7,000	W	Popcorn	Guatemala	1949

Key to Table 1:

O.P. Open pollinated commercial corn.
Sibbed pollinated within the variety.
⊗ Plants selfed within the variety and seed composited using 2 to 12 ears.
2s Plants of the seed selfed once, selfed the second time.
#⊗ Plants sibbed pollinated and selfed.
W Grain White.
Y Grain Yellow.

10A–46. Both of these selections are now in wide use on the Pacific coastal plain of Guatemala. The hybrid was made on the U. S. single cross WF9x38–11. It is thus half Guatemalan and half U. S. in origin. The last entry (200–47 O.P.) in the table was a large late popcorn belonging to the giganteum group *(20)*.

Other data relating to these varieties are given in Table 1, although more detailed description will be published elsewhere *(15)*. All of the seed analyzed was obtained from plants grown in Antigua, Guatemala, from the seed collected as indicated. From the time collected (Table 1) until analysis, they were stored in small sacks on open shelves in an inside room. Five samples of one variety grown during the same growing season in 5 different localities are also included in the study.

Moisture, crude fiber, ether extract, ash, and calcium were determined by A.O.A.C. official methods *(1)*. The digestion for nitrogen determination was done by the official method *(1)* and the distillation and titration as recommended by Hamilton and Simpson *(10)*. Iron was determined by the alpha, alpha′ dipyridyl method of Hill *(12)* as modified by Jackson *(16)* and Moss *(22)*. The whole corn sample was ground approximately 15 mesh in a Hobart Mill before weighing except for mineral assays. In the latter case a porcelain mortar and pestle were used. Correlation coefficients and standard deviations were computed as suggested by Snedecor *(26)*.

RESULTS

The results are given in Table 2. Certain varieties are distinctly superior to others in their total nitrogen content with a range of 1.09 to 1.92 and an average value of 1.52% ($s = 0.22$). Using a conversion factor of 6.25 this represents a range in protein content of the corns of 6.8 to 12.0%. There was a difference in the average nitrogen

TABLE 2

Fat, crude fiber, nitrogen, ash, phosphorus and iron content in twenty-four varieties of corns [b]

Variety no.	Fat	Crude fiber	Nitrogen	Ash	Phosphorus	Iron
	%	%	%	%	*mg./100 gm.*	*mg./100 gm.*
206-44 ⊗	5.54	1.3	1.64	1.85	424	5.14
159–44 # (2s)	6.80	1.2	1.31	1.62	368	3.46
47A–46 O.P.	4.95	1.3	1.69	1.70	345	2.36
1470–46 #	5.74	1.7	1.57	......	......	......
25A–46 ⊗	5.95	1.2	1.49	1.54	364	3.26
92A–46 # ⊗	6.86	1.5	1.29	1.47	343	2.83
192–44 # ⊗	5.65	1.2	1.70	1.41	277	2.61
15A–46 O.P.	4.82	1.4	1.12	1.37	313	2.76
166–44 O.P.	7.32	1.5	1.65	1.44	336	3.54
31–44 #	7.62	1.4	1.20	1.33	303	1.98
20–47 ⊗	5.61	1.1	1.09	1.08	249	2.86
1483–45 ⊗	6.25	1.6	1.21	1.43	311	2.07
21A–46B #	3.80	1.2	1.66	1.60	342	2.99
10A–46 O.P.	4.71	1.5	1.57	1.55	338	2.40
142–48 O.P.	5.02	1.4	1.66	1.42	212	2.08
118A–46 #	5.44	1.4	1.22	1.50	303	2.52
92–44 O.P.	5.00	1.4	1.78	1.55	374	4.96
129A–46 #	4.60	1.8	1.51	1.39	257	2.52
12A–46 # ⊗	6.07	1.7	1.65	1.39	333	2.50
TGY	4.55	1.4	1.54	1.47	222	2.44
1626–45 O.P.	4.48	1.5	1.57	1.51	367	2.96
7A (WF9x38–11)	4.88	1.7	1.61	1.43	226	5.32
26A–46 ⊗	6.36	1.4	1.79	1.50	339	2.56
200–47 O.P.	7.23	1.0	1.92	1.57	401	2.87

Key to Table 2 same as Table 1.
[b] All values expressed at 10% moisture and are the average of two determinations.

of corns grown in 1948 and 1949 with the average value of 1.57% for 1948 being higher than that of 1.44% for the following year.

The ether extractable portion of the corns ranged from 3.80 to 7.62 with an average value of 5.63 ($s = 0.97$). The crude fiber content ranged from 1.0 to 1.8 with an average of 1.40% ($s = 0.21$). The values for fat and crude fiber showed no clear difference in range or average among corns grown in 1948 and 1949. The iron content ranged from 1.98 to 5.32 with an average value of 3.00 mg. per 100 g. ($s = 0.92$). The readiness with which samples for iron assay become contaminated with traces of this element probably accounts for some of the high values and much of the variation. Phosphorus was also determined by the method of Fiske and Subbarow *(7)* as modified by Lowry and Lopez *(19)* and a range of 212 to 424 was obtained. The average phosphorus content was 320 mg. per 100 g. ($s = 58$). Calcium cannot be reported due to the use of a calcium containing dust to protect the samples from insect attack.

The yellow and white corns raised in 1948 and 1949 were compared separately for all the nutriments studied. No consistent differences could be found in nitrogen, crude fiber, and ether extract but, in both 1948 and 1949, the white corns were higher than the yellow corns in phosphorus and iron. Omitting the popcorn (200–47 O.P.) there was a tendency for a negative correlation ($r = -0.57$, 1948 and $r = -0.38$, 1949) between altitude of origin and nitrogen and a positive correlation ($r = +0.56$, 1948 and $r = +0.53$, 1949) between fat and altitude of origin in both years. Thus the nitrogen content appears higher in the varieties originating in the lowlands than in those from the highlands, although none of the correlations are statistically significant at the 5% level. The content of fat tended to be higher in the highland varieties. The crude fiber, ash, and mineral contents showed no such trends.

In order to obtain data relating to the effect of environmental differences on the content of the nutrients discussed, samples of one variety (TGY) were analyzed from 5 localities in the spring growing season of 1951. The results are reported in Table 3

TABLE 3

Fat, crude fiber, nitrogen, ash, phosphorus and iron of variety TGY grown at 5 localities [c]

Origin	Altitude	Fat	Crude fiber	Nitrogen	Ash	Phosphorus	Iron
	feet	%	%	%	%	*mg./100 gm.*	*mg./100 gm.*
Tiquisate	150	5.18	1.8	1.41	1.39	344	2.62
Cuyuta	100	4.60	1.8	1.37	1.43	354	2.49
Retalhuleu	200	4.74	1.9	1.50	1.28	316	2.02
Coatepeque	100	5.19	1.3	1.43	1.18	296	1.84
Antigua	4,953	4.30	1.3	1.52	1.18	284	2.80

[c] All values expressed at 10% moisture and are average of two determinations.

and show a relatively small variation in nitrogen content, 1.37 to 1.52%, despite an altitude range of 100 to 4,953 feet in the localities in which they were grown. The variations in fat, crude fiber, ash, and iron are correspondingly small. The variation in phosphorus, shown in the table, 284 to 354 mg. per 100 g., was also smaller than that among the varieties listed in Table 1.

DISCUSSION

For a population almost wholly dependent on corn for their dietary protein, the differences in protein content reported have considerable practical nutritional significance. The protein contribution of corn to the diet of persons consuming 500 g. of it, a common intake in the Guatemalan highlands, would vary from 34 to 56 g. according to the results of Table 1. All of these corns, except two, as grown in their original localities were eaten by large numbers of people and considered good for their area. By contrast a corn sample selected from Santa María Cauqué and in common use in this village had a protein content equivalent of only 29 g. in 500 g. of corn. Of course, the nutritional value of these corns is dependent upon the quality of the protein as well as its quantity, but qualitative differences could not wholly mask the nutritional effect of quantitative differences of this magnitude. Data relating to the quality of protein in these corns will be discussed in the next two papers of this series.

Differences in the nutritive value of these corns due to variations in the other nutriments listed also occur but are over-shadowed from the point of view of human nutrition by the relatively large differences in protein content. The corns with higher ether extractable portions are markedly higher in caloric value. Since the Central American diets tend to be extremely low in fat, and the fat content of corn often constitutes the bulk of the fat in the diet, these variations may have direct nutritional significance. The differences in ether extractable portion are also of commercial significance to corn milling industries.

The question arises as to what proportion of these differences in composition are due to inherent genetic factors and what proportions to varying cultural and environmental influences. Since the corns were all grown in the same locality the effect of environment should have been minimized. This is true within a single growing season, but all of these corns were not grown in the same year and small differences in rainfall, temperature, and amount of sunshine occurred from year to year. Due to the variations among varieties grown in the same year, it can be stated that a considerable degree of genetic variation in the nutrients studied did occur.

It likewise cannot be expected that these corns would necessarily have the same relative standing if grown in another locality or even the same locality in a year with markedly different climatic conditions *(20)*. Corn is notoriously best adapted to specific environments, and frequently the best corn in a given region does poorly when transferred to a different one *(17, 18)*. The tendency toward a negative correlation of protein content with altitude of origin, although not statistically significant, is suggestive of the relationship of nutrient content to the environment to which the strain is adapted. The tendency of ether extract to be positively correlated with altitude merits comment. Highland corns have a longer maturity period. Although no local data are at present available, it is possible that accumulation of fat may take place in larger amounts than in corns of the lowlands which have a period of maturity of around 100 days. Future studies will be designed to determine the relation of nutritive value to altitude but it is obvious that yield and maturity *(13)* data will be indispensable in the evaluation of the agricultural significance of the phenomena reported or indeed in any studies of the nutritive value of food crops.

The agricultural as well as nutritional significance of the variation in nutritive value of corns reported will be greatly reinforced if the results of Table 3 are borne out by further studies. Relatively wide differences in altitude and other environmental conditions resulted in very small differences in nitrogen content compared with those reported for Table 2. The corn selected was not as well adapted and did not grow as well in the highlands as in the coastal area for which it was developed, yet genetic constitution apparently had a much greater influence on nitrogen content than the considerable environmental differences. The data clearly suggest that the search for and the development and distribution of varieties of corn superior in both yield and nutritive value hold great promise and should be continued, especially in the Central American area where corn is an important human food and shows great genetic variation.

SUMMARY

Twenty-three strains of corn of Guatemalan, Mexican, or Venezuelan origin grown at 5,000 feet in Antigua, Guatemala, together with one Guatemalan-United States hybrid cross were analyzed for moisture, nitrogen, ether extract, crude fiber, iron, and phosphorus. All values were adjusted to an average moisture of 10%. The nitrogen averaged 1.52% ($s = 0.22$), the ether extract 5.63% ($s = 0.97$), crude fiber 1.40% ($s = 0.21$), iron 3.00 mg. per 100 g. ($s = 0.92$) and phosphorus 320 mg. per 100 g. ($s = 58$). All were grown at an intermediate altitude, but there is a tendency for corns from seeds collected at low altitudes to have higher nitrogen and lower fat contents than those obtained from high areas as illustrated by the correlations ($r = -0.57$, $r = +0.56$ in 1948) and ($r = -0.38$, $r = +0.53$ in 1949).

One variety was grown in 5 different locations during the spring growing season of 1951 with relatively little variation in nitrogen content (1.37 to 1.52%) and in the other nutrients measured. It is concluded that although environment also influences nutritional value, important genetic differences in nutritive composition, especially in nitrogen and ether extract, do exist among Guatemalean corns and can be used in the selection of varieties for improved nutritional value.

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