NOTE ON VITAMINS AND TRACE ELEMENTS IN FEEDS DERIVED FROM THE WET-MILLING OF CORN

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Cereal Chemistry 53(6): 964-968

The widespread use of linear programs to prepare least-cost formulations in the feed industry makes it possible to take into account even the minor constituents of the component feedstuffs. Corn wet-milling feed products are used primarily as a source of protein and energy in a variety of animal diets, but these feedstuffs also contain useful concentrations of certain vitamins and trace elements. In this paper, we present the results of the analysis for minor ingredients in annual composite samples taken from three major corn wet-milling plants located in this country.

MATERIALS AND METHODS

Samples

One-pint samples of each of the feed products were taken monthly for a year. The products sampled were high-protein corn gluten meal[1], corn gluten feed[2], condensed fermented corn extractives[3], and solvent-extracted corn germ meal (wet-milled). Each sample was taken by a mechanical sampler over an 8-hr period. Samples were stored in tightly closed jars at 4° C in the dark until all were on hand. Equal weights of the 12 monthly samples of each product from each plant were thoroughly blended. In all cases, at least three-quarters of each sample was taken. The annual composite from each plant was thoroughly mixed, ground if necessary, put through a Riffle-Jones sample divider several times, and a pint sample taken using the same sample divider.

Analyses

Moisture was determined by drying the sample for 4 hr in a vacuum oven at 100° C. The Kjeldahl method was employed for protein using cupric selenite as a catalyst and 6.25 as the factor to convert nitrogen to protein. Total fat content was determined by extraction with 4:1 (v/v) carbon tetrachloride-methanol as the sample was being ground in a ball mill (1). A slight modification of AACC Official Method 77-20 (7th ed.) was used to estimate starch content. Pentosans were analyzed by AOAC procedure 22.050-22.051 (10th ed.).

Microbiological methods were chosen for the determination of biotin, niacin, and free inositol (2). Total inositol was determined after hydrolysis at 15 psi in 3% sulfuric acid for 2 hr. Choline was extracted from the samples with acidic methanol and determined as the reineckate (3).

Many elements were determined by emission spectroscopy (4). Atomic absorption spectroscopy was chosen for the analysis of cobalt, lead, manganese, and zinc. Methods recommended in the Perkin-Elmer manual were used. Mercury was also determined by atomic absorption using the cold vapor technique on a concentrate prepared by chemical means (5). Calcium analysis[4]

[1]Prairie Gold® 60% corn gluten meal.
[2]Buffalo® Kracklets 21% corn gluten feed.
[3]Mazoferm® condensed fermented corn extractives, also known as corn steepwater or corn steep liquor.
[4]F. A. Kurtz and J. J. Wunder. Determination of calcium in feedstuffs. Unpublished results (1966). CPC International, Argo, Ill.

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was accomplished by first precipitating calcium oxalate from a solution of the ash and determining the calcium in the precipitate by titration with EGTA (ethylene glycol bis-(β-aminoethyl ether)N,N-tetra-acetic acid). A gravimetric procedure (AOAC 1.018 to 1.020, 11th ed.) was used to obtain the magnesium values. Arsenic was separated as arsine and determined colorimetrically (AOAC procedure 38.001-006, 11th ed.). The chloride concentration was determined on an aqueous extract by a coulometric procedure using the Aminco-Cotlove instrument. Molybdenum was determined colorimetrically (AOAC procedure 3.052-054, 11th ed.). The total phosphorus content of these samples was determined spectrophotometrically as the molybdovanado-phosphoric acid complex after ashing the sample in the presence of zinc acetate (6). Phytates were separated from the other phosphorus-containing compounds in acidic solution as the iron salt and the total phosphorus content of the salt determined as above. The flame photometer was used to determine potassium on ashed samples. Selenium was determined colorimetrically (7) and sulfur was determined as the sulfate after oxidation in the Parr bomb (8).

RESULTS AND DISCUSSION

Data presented in the tables are averages of the three values obtained on analysis of the annual composites from the three plants. The proximate analyses shown in Table I are similar to those obtained earlier in a much more extensive survey (1). The starch content of the dry feed products averages about 15%, indicating that starch is an important source of energy in these feeds. Both corn gluten feed and corn germ meal contain appreciable amounts of hemicelluloses and this fact is reflected in the high pentosan content of these materials.

Biotin, niacin, and free inositol are not present in high concentrations in feeds derived from the wet-milling of corn (Table II). The amount of niacin may be of some significance only when these feeds form an appreciable percentage of the diet. Although the total inositol content is high, nearly all of it occurs as the phytate and is not available nutritionally. Other vitamins present at low concentration in these feeds, but not determined on these samples, are riboflavin, thiamine, pyridoxine, folic acid, and pantothenic acid (9).

TABLE I
Proximate Composition: Three-Plant Average from Annual Composites (As-Is Basis)

Product	Moisture %	Protein %	Total Fat %	Ash %	Starch %	Pentosans %
High-protein corn gluten meal	11.0	60.6	5.0	2.4	13.8	1.7
Corn gluten feed	10.1	21.4	4.0	7.1	15.0	20.1
Condensed fermented corn extractives	47.9	23.4	0.11	7.7	...	...
Corn germ meal[a]	8.7	23.7	4.0	3.6	15.6	24.9

[a]Annual composite from one plant.

Some problems were encountered in the analysis of choline. Replicate analyses on three samples gave the following results: 0.16 and 0.50%, 0.14 and 0.17%, and 0.39, 0.85, and 0.92%. Fritz (3) has commented on the poor reproducibility of this method and identified the extraction as the probable cause. Data in Table II are an average of all values obtained.

Results of the determination of the minor elements in feeds from the wet-milling of corn are shown in Table III. Those elements normally associated with toxic reactions are present in very low concentrations in these feeds. Only corn germ meal contained a measurable amount of arsenic (0.06 ppm). The other feeds contained less than 0.05 ppm. The mercury concentration in all these feeds is also less than 0.05 ppm. Although 0.3 and 2.2 ppm of lead are present in these feeds, this level constitutes no hazard (10). Less than 1 ppm selenium is present in all products.

The principal cation in corn is potassium and, as anticipated, it concentrates in the steepwater. An appreciable concentration is also found in corn gluten feed because steepwater is added to this product. Sodium is present in much lesser concentrations.

Magnesium occurs in these feeds in much higher concentrations than calcium. Magnesium is present as a soluble phytate and therefore concentrates in the steepwater. Calcium is present as an insoluble compound which collects in gluten feed.

The phytates in corn are soluble under steeping conditions (pH 4) and concentrate in the steepwater. Two-thirds of the phosphorus in steepwater occurs as phytate, whereas less than 15% of the phosphorus in high-protein corn gluten meal or corn germ meal is phytate.

The high aluminum content of corn germ meal is due to the presence of spent bleaching earth from the oil refinery.

Two different methods were used to analyze for magnesium, manganese, potassium, and zinc. In all cases, emission spectroscopy was one method; the other method was chosen because we were more familiar with it. Results by emission spectroscopy for magnesium varied considerably from the results obtained by the gravimetric method. In high-protein corn gluten meal, the emission results averaged 25% higher; on the corn extractives they were 18%

TABLE II
B Vitamins in Feeds from Corn Wet-Milling (As-Is Basis)

Product	Biotin ppm	Niacin ppm	Inositol, % Total	Inositol, % Free	Choline %
High-protein corn gluten meal	0.20	79	0.19	0.020	0.45
Corn gluten feed	0.19	74	0.54	0.033	0.24
Condensed fermented corn extractives	0.33	83	0.60	0.027	0.35
Corn germ meal[a]	0.18	43	0.23	0.016	0.14

[a]Annual composite from one plant.

TABLE III
Minor Elements in Feeds from Corn Wet-Milling (As-Is Basis)

Element	Method	High-Protein Corn Gluten Meal[a]	Corn Gluten Feed[a]	Cond. Ferm. Corn Ext.[a]	Corn/Germ Meal
Aluminum	Emission	25 ppm	246 ppm	5 ppm	407 ppm
Arsenic	AOAC	<0.05 ppm	<0.05 ppm	<0.05 ppm	0.06 ppm
Barium	Emission	<1 ppm	2.2 ppm	<0.4 ppm	3.5 ppm
Boron	Emission	7 ppm	13 ppm	13 ppm	11 ppm
Calcium	EGTA	0.02 %	0.14 %	0.02 %	0.04 %
Chloride	Coulometric	0.10 %	0.23 %	0.43 %	0.04 %
Chromium	Emission	<1.5 ppm	<1.5 ppm	0.9 ppm	<1.5 ppm
Cobalt	Atomic	<0.05 ppm	0.08 ppm	<0.05 ppm	0.07 ppm
Copper	Emission	22 ppm	15 ppm	10 ppm	4 ppm
Iron	Emission	167 ppm	304 ppm	113 ppm	340 ppm
Lead	Atomic	0.3 ppm	2.2 ppm	0.3 ppm	1.1 ppm
Magnesium	Emission	0.15 %	0.42 %	0.58 %	0.16 %
	Gravimetric	0.12 %	...	0.71 %	0.15 %
Manganese	Emission	2 ppm	20 ppm	25 ppm	4 ppm
	Atomic	...	21 ppm	26 ppm	8 ppm
Mercury	Atomic	<0.05 ppm	<0.05 ppm	<0.05 ppm	<0.05 ppm
Molybdenum	AOAC	0.6 ppm	0.8 ppm	1.0 ppm	0.5 ppm
Total phosphorus	Colorimetric	0.69 %	0.92 %	1.8 %	0.56 %
Phytin phosphorus	Colorimetric	0.10 %	0.43 %	1.2 %	0.05 %
Potassium	Emission	0.47 %	1.3 %	2.7 %	0.34 %
	Flame Phot.	0.38 %	...	...	0.12 %
Selenium	Colorimetric	0.91 ppm	0.23 ppm	0.34 ppm	0.34 ppm
Sodium	Emission	0.03 %	0.12 %	0.12 %	0.04 %
Strontium	Emission	2.8 ppm	3.6 ppm	2.0 ppm	3.4 ppm
Sulfur	Parr Bomb	0.83%	0.46 %	0.59 %	0.32 %
Zinc	Emission	41 ppm	89 ppm	65 ppm	105 ppm
	Atomic	29 ppm	75 ppm	90 ppm	85 ppm

[a]Average of annual composites from three plants.

lower. We feel the gravimetric results are more accurate. Atomic absorption spectroscopy was used to determine the concentration of manganese in these samples; agreement with the emission spectroscopy data was good except for germ meal where the emission result (4 ppm) was half that obtained by atomic absorption. Only high-protein corn gluten meal and corn germ meal were analyzed for potassium by both flame photometric and emission spectroscopic techniques. In both cases, results by flame photometry were considerably lower. The results obtained by atomic absorption spectroscopy for zinc are probably more nearly correct than those obtained by emission spectroscopy due to the fact that sodium tends to interfere with the determination of zinc by the latter method.

These data were obtained as part of an ongoing program to provide the feed industry with sound information on the composition of the feeds from corn wet-milling. We hope in a few years to update the most useful parts of this information.

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[Received September 15, 1975. Accepted March 27, 1976]