COMPOSITION OF RICE

Influence of Variety and Environment On Physical and Chemical Composition

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Information on the influence of variety and environment of growth on the physical and chemical composition of rice was needed. Examination of eight varieties of rice grown during 3 years at three locations indicated that both variety and environment have a highly significant influence on yields of milling and anatomical fractions of rough rice and the composition of the true bran; variety has a significant influence on the lipide content of white rice and a highly significant influence on the nitrogen content of white rice and the ash content of hulls; and environment has a highly significant influence on the ash content of hulls and on the lipide, nitrogen, ash, and starch content of the white rice. White rice is very low and rice bran high in total phosphorus. Phytin phosphorus is 40 and 90% of the total phosphorus present in white rice and rice bran, respectively. White rice contains only trace quantities of sodium. Systematic data on the physical and chemical composition of rice provide basic information for those concerned with the production, processing, and utilization of rice.

RICE IS ONE OF THE MOST IMPORTANT of cereal crops, the staple of over a third of the world's population, but the literature does not report any systematic investigations on the influence of variety and environment on its physical and chemical composition. Kik (*13*) has studied some effects of these factors on the thiamine, riboflavin, and niacin contents. He found that the thiamine and riboflavin content differs between varieties, and, to a slight extent, between locations. Only small varietal differences and an insignificant influence of location were observed with respect to niacin.

The present report deals with a symmetrically designed investigation on the variability in the composition of rice of eight commercial varieties. The results are expected to be of interest in the processing and utilization of rough rice and its products.

Samples

The experimental samples were of eight commercial varieties of rice grown at three locations during 1948, 1949, and 1950 by the Division of Cereal Crops and Diseases of the Bureau of Plant Industry, Soils, and Agricultural Engineering. The locations and varieties are given in Table I. As the mature rice samples were received, they were placed in sealed containers, and stored at 0° F. The samples were allowed to warm to room temperature before the containers were opened for milling the rice.

One kilogram of a representative sample of each of the 72 lots of rice was milled quantitatively using the McGill experimental equipment. The McGill sheller was used to remove the hulls, and the brown rice was then passed through a McGill miller to remove the bran. The adjustments used on these machines were those recommended by the Grain Branch of the Production and Marketing Administration (*32*). The hull and bran fractions were essentially free of each other, but some of the endosperm was included in the bran. In order to prevent changes in the composition of the bran fractions after milling, they were stored at 0° F. until analyzed.

Influence of Variety and Environment On Physical and Chemical Composition

The physical composition of the whole rice was obtained from the milling yields. The chemical composition of each of the milling fractions was determined. The samples were analyzed by recognized methods: starch in the bran colorimetrically (*10*) and in the white rice polarimetrically (*3*); nitrogen by the Kjeldahl method; moisture in the rough rice, hulls, and whole and ground white rice by drying 5-gram samples for 3 hours at 130° C. in a forced draft oven; moisture in the bran by the same procedure but using a 2-gram sample; ash by burning for 4 hours at 600° C. in a muffle furnace; and lipides in the bran and white rice by extraction of a 4-gram sample for 4 hours with commercial hexane (*1*).

Results and Discussion

Physical Composition of Rough Rice. The average milling yields of hull, bran, and white rice, calculated to a dry matter basis, are tabulated in Table I.

The average yield of hulls was 20.7%, with individual values varying from 17.1% for Caloro rice grown at Stuttgart in 1950 to 22.6% for Prelude and Blue Rose rice grown at Stuttgart in 1948 and at Crowley in 1949, respectively.

Milling yields of bran ranged from 6.2% for Bluebonnet grown at Stuttgart in 1950 to 9.4% for Early Prolific grown at Crowley in 1948 with an average value of 7.6% as compared to a commercial average of 8.5% (*24*).

The mean yield of white rice was 71.7%. Examination of the values indicates that samples grown at Stuttgart gave the highest average yield of white rice, while Caloro averaged highest among the varieties examined. Samples

Table I. Summary of Physical Composition of Rice

(Moisture-free basis)

Location and Variety	Rough Rice, %: Hulls	Rough Rice, %: Bran, Milled fraction	Rough Rice, %: Bran, Pericarp and germ	Rough Rice, %: White Rice, Milled fraction	Rough Rice, %: White Rice, Total endosperm	Bran, Brown Rice, %: Milled fraction	Bran, Brown Rice, %: Pericarp and germ
Stuttgart, Ark.	20.4	7.3	6.5	72.3	73.2	9.2	8.2
Crowley, La.	21.2	7.8	6.9	71.0	71.9	9.9	8.8
Beaumont, Tex.	20.5	7.8	6.9	71.7	72.6	9.8	8.7
Caloro	18.5	8.0	7.1	73.5	74.4	9.8	8.7
Blue Rose	21.1	7.6	6.9	71.4	72.0	9.6	8.7
Early Prolific	21.4	8.1	7.1	70.5	71.4	10.3	9.0
Zenith	21.6	7.8	6.9	70.6	71.5	9.9	8.8
Fortuna	20.8	7.0	6.2	72.1	73.0	8.8	7.8
Prelude	21.9	7.8	6.8	70.2	71.2	10.0	8.7
Magnolia	20.0	7.6	7.0	72.4	73.0	9.5	8.8
Bluebonnet	20.1	7.0	6.1	72.8	73.8	8.8	7.6
High (individual)	22.6	9.4	8.0	75.8	76.7	12.1	10.3
Low (individual)	17.1	6.2	5.5	68.5	69.7	7.5	6.6
Mean	20.7	7.6	6.8	71.7	72.5	9.6	8.6
Standard deviation	±1.41	±0.67	±0.60	±1.73	±1.64	±0.92	±0.81
Analysis of variance, F values[a]							
Varieties	18.2[b]	8.7[b]	16.6[b]	12.4[b]	14.7[b]	7.8[b]	14.1[b]
Station years	5.4[b]	9.1[b]	14.2[b]	7.1[b]	8.0[b]	8.9[b]	13.0[b]

[a] $N = 8$ for varieties; $N = 9$ for station years.
[b] Highly significant.

from Crowley showed the lowest average yield for stations and Prelude the lowest average yield for varieties. Analysis of variance on the data (Table I) showed that both environment and variety had a highly significant effect on the milling yields.

The hulls were completely separated from the brown rice by the milling process, but some of the endosperm was unavoidably included in the bran fraction. In order to determine where and to what extent constituents occur in rice it was necessary to calculate the data to the true anatomical basis. Because no starch occurs in the pericarp layers (bran) (*35*), the starch contents of the bran and white rice fractions were used to correct the yields and chemical analyses to a basis of endosperm and true bran. The amounts of included endosperm ranged from 7.99 to 13.05% and averaged 11.16% of the bran fraction. Averages of the milling data, calculated to the anatomical basis in this way, are also given in Table I. Analysis of variance indicated that on this basis as well as on the actual milling yields, the influence of both environment and variety was highly significant statistically.

Composition of Hulls. The only constituent determined on the hulls was ash, average values of which are tabulated in Table II. It is apparent from the analysis of variance that both variety and location of growth exert a highly significant influence on the ash content of the hulls.

Composition of Pericarp plus Germ. Average values for the constituents of the pericarp and germ fraction are given in Table II. Most of the lipides in the rice grain occur in this fraction. The mean lipide content for all samples was 23.91% with individual values ranging from 18.42 to 29.81%. It is apparent that both varietal and environmental effects are highly significant statistically, the F values being 19.59 and 19.69, respectively. Iodine values of the oil ranged from 97.1 to 104.5, indicating a limited variation in degree of unsaturation. Highly significant effects of both variety and environment were observed. It appears from covariance analysis that no relationship exists between the iodine value and the oil content, since the correlation coefficients were low in all instances.

The mean nitrogen content of the pericarp plus germ fraction was 2.90%. As in the case of the lipide content, varietal and environmental effects are both highly significant.

Ash contents of individual samples vary from 10.05 to 15.27% with a mean value of 12.32%. The influence of environment is statistically significant at the 1% level, while that of variety is significant only at the 5% level. The higher mean square due to station years probably reflects variation in inorganic constituents of the soil, as the flooding of rice fields during growth supplied excess moisture in all cases.

Composition of Endosperm (White Rice). The major constituent of rice is starch, which makes up about 70% of the whole grain. Starch content of the endosperm (Table III) ranges from 87.2 to 93.5% and averages 90.2%. Although the station means do not vary over a large range, analysis of variance shows a highly significant environmental and a nonsignificant varietal effect, indicating that variation in the starch content of white rice is largely due to environment.

Both environment and variety have a highly significant influence on the nitrogen content of the endosperm. Individual values ranged from 0.96 to 1.60% and averaged 1.29%.

Rice endosperm is low in both ash and lipides, the average values being 0.48 and 0.54%, respectively. Highly significant environmental effects are indicated by the data, while varietal effects are nonsignificant for the ash and significant

Table II. Summary of Chemical Composition of Rice Hulls and True Bran

(Moisture-free basis)

Location and Variety	Hulls Ash, %	Pericarp and Germ Fraction: Ash, %	Pericarp and Germ Fraction: Nitrogen, %	Pericarp and Germ Fraction: Lipides, %	Pericarp and Germ Fraction: Iodine value of lipides, Wijs
Stuttgart, Ark.	25.14	13.01	2.75	24.16	101.7
Crowley, La.	24.29	11.74	2.96	23.76	100.6
Beaumont, Tex.	23.90	12.20	3.00	23.79	100.8
Caloro	21.82	11.74	2.90	22.93	103.2
Blue Rose	24.90	12.46	2.98	23.91	98.5
Early Prolific	24.83	12.04	3.03	21.96	101.5
Zenith	22.35	11.93	2.86	24.70	101.8
Fortuna	26.38	12.99	2.90	24.38	101.3
Prelude	23.88	12.25	2.83	21.80	100.4
Magnolia	26.13	12.60	2.97	25.31	100.7
Bluebonnet	25.28	12.52	2.75	26.25	100.9
High (individual)	29.04	15.27	3.22	29.81	104.5
Low (individual)	19.03	10.05	2.55	18.42	97.1
Mean	24.45	12.32	2.90	23.91	101.0
Standard deviation	±2.10	±1.20	±0.17	±2.37	±1.46
Analysis of variance, F values[a]					
Varieties	35.9[b]	2.5[c]	12.4[b]	19.7[b]	74.0[b]
Station years	18.4[b]	12.6[b]	23.4[b]	19.6[b]	14.0[b]

[a] $N = 8$ for varieties; $N = 9$ for station years.
[b] Highly significant.
[c] Significant.

Table III. Summary of Chemical Composition of Rice Endosperm

(Moisture-free basis)

Location and Variety	Endosperm, % Ash	Nitrogen	Lipides	Starch
Stuttgart, Ark.	0.47	1.20	0.48	91.0
Crowley, La.	0.46	1.26	0.56	90.4
Beaumont, Tex.	0.50	1.41	0.59	89.3
Caloro	0.48	1.28	0.53	90.1
Blue Rose	0.48	1.34	0.55	89.6
Early Prolific	0.46	1.21	0.52	90.8
Zenith	0.47	1.25	0.60	90.3
Fortuna	0.50	1.29	0.56	89.9
Prelude	0.45	1.31	0.41	90.7
Magnolia	0.48	1.36	0.58	90.1
Bluebonnet	0.49	1.30	0.61	90.4
High (individual)	0.61	1.60	0.95	93.5
Low (individual)	0.36	0.96	0.26	87.2
Mean	0.48	1.29	0.54	90.2
Standard deviation	±0.06	±0.15	±0.15	±1.34
Analysis of variance, *F* values[a]				
Varieties	1.0	3.9[b]	2.7[c]	2.0
Station years	5.6[b]	29.4[b]	6.3[b]	14.6[b]

[a] $N = 8$ for varieties; $N = 9$ for station years.
[b] Highly significant.
[c] Significant.

only at the 5% level for the lipide content.

Examination of the data for the chemical constituents in the endosperm by covariance shows a highly significant negative correlation between starch and nitrogen contents, most of which is attributable to the effect of station years.

Distribution of Phosphorus Compounds In White Rice and Rice Bran

The importance of phosphorus in human and animal nutrition is well recognized, and much consideration has been given to the availability of phosphorus as influenced by the type of compound in which it occurs in foods and feeds (*15, 16, 25, 27, 28*). However, only limited systematic information is available on the distribution of these compounds in the food and feed products of various plants, including those of rice. A number of investigators have analyzed rice products for total and phytin phosphorus (*2, 6, 18, 23, 26, 29, 31*). Amounts of total, phytin, phosphatide, nucleic, and inorganic phosphorus have been reported for rice embryo and whole grain (*4*) and for rice grain and straw (*9*). The order of abundance of phosphorus compounds in whole grain and bran of rice of two varieties has been given as phytin, nucleic, inorganic, and phosphatide, and in the endosperm of the rice kernel as mostly nucleic and phytin phosphorus (*30*).

The importance of rice as a food and the use of rice bran as a feed have justified the determination of the distribution of phosphorus compounds in white rice and rice bran as part of an investigation of the influence of variety and environment on the composition of rice.

Samples and Methods Of Analysis The white rice and rice bran were composited according to location and variety to provide 11 samples for analysis. Three represented the production at each of three stations of eight varieties during 3 years. Eight represented each of eight varieties grown at the three stations during the 3 years.

Total, acid-soluble, phytin, inorganic, and phosphatide phosphorus were determined by use of an analytical system developed for their determination in plant materials (*21*). Nucleic and carbohydrate phosphorus were estimated by difference, using the values found for other types present (*21*).

Results and Discussion The amounts of the various phosphorus compounds found in the composite samples of white rice are given in Table IV in terms of milligrams of phosphorus per gram of sample. Variations in the values for the individual compounds are comparatively small. Statistical examination of the present data indicated that neither variety nor environment has any significant influence on any of the compounds. The significant observation is that the total phosphorus content of white rice is low and that a considerable portion of it is present as phytin phosphorus.

The amounts of the phosphorus compounds in true rice bran are tabulated in Table V. The values given for the true bran, consisting of the pericarp and germ, were derived from analyses of the bran as milled from rough rice. Accepting the observation that the pericarp contains no starch (*35*), the adjustment of the analytical results was made from the starch content of the bran samples and the starch and phosphorus contents of the white rice. The average amount of endosperm included in the bran fraction was 11.16%. It was assumed that the composition of this material was the same as that of the white rice. Consequently the results are somewhat higher than for commercial rice bran.

As in white rice, variations in any particular phosphorus compound in rice bran are relatively small (Table V) and were not found to be significantly influenced by environment or variety. The true bran is very high in total phosphorus, with phytin phosphorus comprising the major portion.

The average distribution of the phosphorus compounds in white rice and true bran, when calculated as percentages of the total phosphorus (Table VI), demon-

Table IV. Phosphorus Distribution in Composite Samples of Moisture-Free White Rice

Station and Variety	Phosphorus Compounds, Mg. of Phosphorus per Gram of White Rice: Total	Acid-soluble	Phytin	Inorganic	Phosphatide	Nucleic	Carbohydrate
Station							
Stuttgart, Ark.	1.13	0.60	0.41	0.038	0.009	0.52	0.16
Crowley, La.	1.12	0.61	0.42	0.033	0.007	0.51	0.15
Beaumont, Tex.	1.18	0.68	0.52	0.036	0.008	0.49	0.12
Station mean	1.14	0.63	0.45	0.036	0.008	0.51	0.14
Variety							
Caloro	1.10	0.60	0.44	0.035	0.008	0.50	0.12
Blue Rose	1.07	0.53	0.37	0.031	0.008	0.54	0.13
Early Prolific	1.00	0.54	0.38	0.034	0.009	0.46	0.13
Zenith	0.96	0.46	0.36	0.019	0.011	0.49	0.08
Fortuna	1.13	0.54	0.44	0.025	0.010	0.58	0.08
Prelude	1.01	0.47	0.35	0.034	0.008	0.53	0.08
Magnolia	1.00	0.55	0.55	0.038	0.011	0.44	0.00
Bluebonnet	1.21	0.65	0.55	0.024	0.010	0.55	0.08
Variety mean	1.06	0.54	0.43	0.030	0.009	0.51	0.09
Standard deviation	±0.082	±0.060	±0.080	±0.007	±0.001	±0.048	±0.042
Over-all mean	1.10	0.58	0.44	0.033	0.008	0.51	0.11

strates a striking difference in their distribution in white rice and bran. For white rice, nucleic phosphorus comprises 46.1% and phytin phosphorus 39.9% of the total. In contrast to this, the nucleic phosphorus of true rice bran accounts for only 4.4%, while phytin phosphorus makes up 89.9% of the total. Thus in white rice, some 60% of the total phosphorus is present as nonphytin phosphorus and is presumably available to humans (*12*, *23*). Since only about 10% of the phosphorus in the true bran is present as nonphytin phosphorus, the availability of phytin should be considered in connection with the use of rice bran as a feed.

Table VI. Average Distribution of Phosphorus Compounds in White Rice and True Rice Bran

(Pericarp and germ)

Product	Phosphorus in Compounds, % of Total Phosphorus: Acid-soluble	Phytin	Inorganic	Phos-phatide	Nucleic	Carbo-hydrate
White rice	53.1	39.9	3.0	0.8	46.1	10.3
Bran	94.6	89.9	2.5	1.0	4.4	2.3

Inorganic Constituents in Hulls, Bran, and White Rice

As the inorganic constituents are important to the utilization of plant products, whether for food, feed, or use as industrial raw materials, those in the milling fractions of rough rice have been re-examined to obtain systematic and more complete data. Most of the data found in the literature are for rice grown in the Orient (*5*, *11*, *14*, *19*, *33*, *34*). Very little attention has been given the complete analysis of the ash of the hulls, bran, and white rice and to the amounts of the trace metallic elements in these fractions, especially from rice grown domestically. The information on white rice should prove valuable to those interested in using it in special diets.

Samples and Method Of Analysis

The individual samples of hull, bran, and white rice were composited by location of growth and by variety. Thus, each location and variety composite represented 24 and nine individual samples, respectively.

For the determination of the major inorganic constituents, appropriate amounts of the composite samples of hulls, bran, and white rice were used to obtain approximately 1 gram of ash. Each sample was ashed in duplicate for 4 hours at 600° C. in an electric muffle furnace. In the case of the white rice it was necessary first to char the samples by means of a suspended infrared strip heater to aid in the incineration of the large amount of starch. The ash from each sample was analyzed for silica, calcium, magnesium, potassium, sodium, and sulfur by the methods of the Association of Official Agricultural Chemists for plant materials (*3*). Separate ashings were made for the determination of chlorine by precipitation with silver nitrate (*3*) and for phosphorus by the reduced molybdate method (*21*).

The amounts of aluminum, copper, iron, manganese, and tin were determined spectrochemically by the line-width method of Coheur (*7*) as applied to a general method for plant products (*20*).

Discussion Of Results

Statistical analysis of the data did not indicate any significant influence of variety of rice or environment on the amounts of the inorganic constituents determined. For this reason only a summary of the results is tabulated.

The data for the major ash constituents are shown in Table VII as percentages of the ash. The principal component of the hull ash is silica, which averaged 96.62%. This value is somewhat higher than those reported for rice hulls from foreign sources (*5*, *14*, *34*), but is comparable with those for domestic varieties (*8*, *33*). Small amounts of potassium, magnesium, calcium, sulfur, phosphorus, and chlorine are present.

A considerable portion of the bran ash is accounted for by phosphorus, although appreciable amounts of potassium, magnesium, and silica are present. The amounts of calcium and chlorine found were very small, while both sodium and sulfur were below the level of quantitative determination by the methods used.

The composition of the white rice ash is similar to that from the bran, in that phosphorus is the major constituent. As would be expected of plant materials, considerable potassium is present. Other constituents include magnesium, calcium, chlorine, and silica. No sulfate or sodium was found in any of the samples by the analytical procedures followed.

Spectrochemical data for several trace elements, expressed as parts per million of the dry hulls, true bran, and white rice are summarized in Table VIII. Aluminum, copper, iron, and manganese were found in all samples in concentrations that could be measured quantitatively by the spectrochemical method. Tin was present in all the white rice and rice bran samples but absent in the hulls. Examination of the spectrograms showed the presence of traces of barium, boron, and zinc. No traces of cobalt, chromium, germanium, lead, or vanadium were detected. Very weak lines due to sodium were present in most of the spectrograms, indicating that this element is present only in very minute traces. This accounts for the use of rice in special diets where a restricted sodium intake is required.

The concentration of the trace metals in rice bran is considerably greater than that of the white rice, while the corresponding concentrations in the hulls are intermediate between those of the bran and white rice.

Table V. Phosphorus Distribution in Composite Samples of Moisture-Free True Rice Bran

(Pericarp and germ)

Station and Variety	Phosphorus Compounds, Mg. of Phosphorus per Gram of True Bran: Total	Acid-soluble	Phytin	Inorganic	Phos-phatide	Nucleic	Carbo-hydrate
Station							
Stuttgart, Ark.	27.98	26.21	25.14	0.72	0.20	1.57	0.35
Crowley, La.	25.55	24.58	23.17	0.64	0.27	0.70	0.77
Beaumont, Tex.	26.10	24.28	23.03	0.58	0.32	1.50	0.67
Station mean	26.54	25.02	23.78	0.65	0.26	1.26	0.60
Variety							
Caloro	24.76	23.55	22.31	0.66	0.23	0.98	0.58
Blue Rose	26.97	23.86	22.65	0.66	0.30	2.81	0.55
Early Prolific	24.94	23.89	22.83	0.72	0.25	0.80	0.34
Zenith	25.76	23.74	22.53	0.70	0.28	1.74	0.51
Fortuna	28.68	27.84	26.37	0.62	0.26	0.58	0.85
Prelude	25.26	24.89	23.57	0.72	0.30	0.07	0.60
Magnolia	26.83	26.24	24.56	0.75	0.33	0.26	0.93
Bluebonnet	28.18	26.71	25.70	0.54	0.30	1.17	0.47
Variety mean	26.42	25.09	23.82	0.67	0.28	1.05	0.60
Standard deviation	±1.48	±1.63	±1.56	±0.067	±0.033	±0.88	±0.20
Over-all mean	26.48	25.06	23.80	0.66	0.27	1.16	0.60

Summary

Eight varieties of rice grown for 3 years at three locations were examined to ascertain the effects of variety and environment on the physical and chemical composition.

Table VII. Inorganic Constituents in the Ash of Hulls, True Bran (Pericarp and Germ), and White Rice[a]

Product	Ash, %	Composition of Ash, %							
		SiO_2	Ca	Mg	Cl	K	Na	S	P
Hulls									
High	26.38	97.10	0.28	0.54	0.50	2.10	0.00	0.30	0.28
Low	21.83	96.22	0.18	0.36	0.36	0.95	0.00	0.15	0.16
Mean	24.45	96.62	0.23	0.46	0.42	1.32	0.00	0.20	0.22
Std. dev.	±1.41	±0.30	±0.036	±0.052	±0.045	±0.37	0.00	±0.042	±0.037
True Bran									
High	11.56	14.07	0.67	10.65	0.84	19.67	0.00	0.00	21.77
Low	10.43	11.55	0.49	9.37	0.49	16.96	0.00	0.00	20.25
Mean	10.94	12.58	0.55	10.14	0.70	18.02	0.00	0.00	21.42
Std. dev.	±0.43	±0.92	±0.051	±0.43	±0.10	±0.88	0.00	0.00	±0.47
White Rice									
High	0.48	3.76	1.24	7.76	7.89	20.96	0.00	0.00	24.70
Low	0.43	2.49	0.95	5.32	4.76	15.00	0.00	0.00	20.58
Mean	0.46	3.00	1.11	6.90	5.71	18.63	0.00	0.00	23.37
Std. dev.	±0.017	±0.34	±0.10	±0.81	±1.27	±1.66	0.00	0.00	±1.27

[a] Moisture-free basis.

Both variety and environment had a highly significant effect on the milling yields and on the yields of true anatomical fractions of the rice grain. Their influence on the composition of the pericarp and germ fraction was also highly significant, except in the case of the ash content, where the influence of variety was significant only at the 5% level.

Variety had no significant effect on the starch or ash content of white rice and was significant only at the 5% level in its effect on the lipide content. However, it had a highly significant effect on the nitrogen content of white rice and on the ash of the hulls. Environmental effects were highly significant on the ash content of the hulls and on the lipide, nitrogen, ash, and starch contents of the endosperm.

White rice is very low in total phosphorus, averaging 1.1 mg. per gram, while rice bran is high in total phosphorus, averaging 26.5 mg. per gram.

Phytin phosphorus accounted for 39.9%, nucleic 46.1%, carbohydrate 10.3%, inorganic 3.0%, and phosphatide 0.8% of the total phosphorus in white rice. The distribution in the true rice bran is somewhat different, with phytin phosphorus comprising 89.9%, nucleic 4.4%, inorganic 2.5%, carbohydrate 2.3%, and phosphatide 1.0% of the total phosphorus.

Trace elements present in all samples include aluminum, copper, iron, and manganese as well as detectable amounts of barium, boron, and zinc. Tin was found in the white rice and bran samples.

Statistical analysis of the data did not indicate any significant influence of variety or environment on the amounts of the inorganic constituents.

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Table VIII. Trace Metals in Hulls, True Bran (Pericarp and Germ), and White Rice[a]

Product	Al, P.P.M.	Cu, P.P.M.	Fe, P.P.M.	Mn, P.P.M.	Sn, P.P.M.
Hulls					
High	98.2	2.59	59.5	559	
Low	29.8	1.45	23.6	210	
Mean	59.0	1.91	45.0	402	0.00
Std. dev.	± 19.65	±0.38	±11.89	±123.25	
True bran					
High	369	25.0	316	877	41.3
Low	53.5	6.99	140	406	17.6
Mean	232	15.64	224	697	23.8
Std. dev.	±103.69	±5.70	±64.33	±138.0	±6.66
White rice					
High	7.23	3.10	26.8	13.6	1.78
Low	0.73	1.72	4.63	9.90	0.93
Mean	2.62	2.36	10.51	10.96	1.34
Std. dev.	± 1.85	±0.44	± 6.48	± 1.19	±0.24

[a] Moisture-free basis.

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PECTIN PRODUCTION

Pilot Plant Production of Low-Methoxyl Pectin from Citrus Peel

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Low-methoxyl pectins are versatile materials which make possible the preparation of many new food products and the preparation of old food products in new or easier ways. Use of various modified pectins is restricted, however, by limited availability. Suitable grades and types of low-methoxyl pectin can be prepared in good yield from citrus peel. Care is required throughout the manufacturing operation to avoid excessive loss of pectin quality. Procedures have been developed on a pilot plant scale. Three stages are involved: preparation of peel for extraction, extraction of pectin and clarification of the extract, and chemical modification and isolation of low-methoxyl pectin. All operations are conducted in an aqueous phase, in contrast to present production methods. An integrated, practical process for making low-methoxyl pectin from citrus peel has been developed. Operating conditions, procedures, and equipment are discussed in a manner designed to assist prospective users of the process.

LOW-METHOXYL PECTIN is a comparatively recent development, although pectin has been manufactured in the United States for more than 35 years (*15*). The many methods reported in the literature for the preparation of low-methoxyl pectins have been based on laboratory scale experiments. Little if any information has been published on production methods used by the several manufacturers who have made low-methoxyl pectin on a commercial scale.

Pectin is largely the partial methyl ester of anhydrogalacturonic acid and, as extracted from common source materials, contains ordinarily from 9 to 12% by weight of methoxyl groups. When a substantial portion of the methyl ester groups is removed by hydrolysis, the modified pectin attains the ability to form uniform strong gels in the presence of bivalent cations over a wide pH range. This property makes low-methoxyl pectin useful for numerous applications in which ordinary pectin cannot be used. Applications suggested for low-methoxyl pectin include jellied fruit cocktail (*14*), tomato aspic (*19*), low-solids gels (*3*, *5*, *19*, *28*), milk puddings (*19*, *31*), candy centers (*10*), and coatings for various food materials (*27*). Numerous patented applications are not reviewed here.

This paper summarizes the development of a process for making low-methoxyl pectin from citrus peel. The process is divided into three parts: preparation of the peel, extraction of pectin from the peel and clarification of the extract, and processing of the extract to prepare the dry, low-methoxyl pectin product. Processing of the pectin extract involves the controlled de-esterification of the pectin, isolation of the low-methoxyl pectin by acid precipitation, dewatering and neutralizing of the low-methoxyl pectin, and drying and grinding to make the final product.

Pectin is a long-chain molecule which is de-esterified and degraded (reduced in chain length) by heat, acidity, alkalinity, and enzyme action. The quality—i.e., the gelling ability—of a pectin product is controlled largely by the chain length of the molecule—the longer the chain, the higher the quality. Most of the pectin in fresh citrus peel is fairly insoluble in cold water. Heat and acid are used to render the pectin extractable, but these agents also degrade the pectin. The amount of degradation must be limited, so that satisfactory quality is