the preliminary and intermediate phases drastic destruction of carotene, regular increases in fluorescence, and sharp increases in fat acidity. The end of the intermediate stage referred to may be considered the change in color of the material from brown to black.

The data suggest that deterioration was extremely advanced in terms of color and chemical deterioration before flaming combustion appeared. The evidence for this is the regular change in most of the analytical values to a condition where the pellets are very dark brown in color. With the appearance of the final black stage of heating, however, these gradual and regular changes become very abrupt transitions and even reversals in trend in most of the analytical values, such as occurred here in passing from the D (dark brown) to the E and F samples. It seems probable that if flaming combustion were involved, it occurred at a stage of deterioration not earlier than that represented by sample E, which was entirely black. Sample F of this series exhibited what appeared to be ash on the surface of the pellets. It may also be surmised, as has been indicated for other spontaneously heating materials (*7*), that flaming combustion probably would not occur so long as the material in the dark brown stage was not exposed to oxygen, as happens in salvage operations. Undisturbed large masses of heating granular biological materials have been known to become "spent" and may eventually cool without attaining flame.

The present data parallel those previously published for spontaneously heating soybeans, with the significant exception that no visual evidence of storage molds could be found on any of the pellets, in spite of very careful examination of numerous samples at the moment of salvaging. The pattern of change in fat acidity as well as that of other chemical values also argues against a major involvement of biological factors in the deterioration. It may be considered, therefore, that alfalfa pellets are even more susceptible to the spontaneous heating than are soybeans and that such heating may involve products of the Maillard reaction. This conclusion may not be surprising when consideration is given to the composition of alfalfa pellets and the fact that extensive mechanical rupture of the plant tissues and forceful mixing of cell constituents occur during the grinding, drying, and pelleting operations. Doubtless the elevated temperatures and pressures used in the pelleting operation also favor the initiation of browning phenomena.

The nutritive and commercial value of the pellets as represented by the various stages of deterioration from A to F and the influence on these values of various amounts of these materials mixed into otherwise sound pellets cannot be established by analyses of these kind alone. Only feeding trials with animals will indicate clearly the extent of nutritive impairment. Feeding value, as determined, say, with chickens, would not be necessarily pertinent to that for cattle. Nevertheless it is clear that the loss of carotene and sugars and the formation of browning products which are known to reduce the nutritive availability of the proteins, would seriously affect nutritional quality of these alfalfa pellets in proportion to the extent of heating. Furthermore, studies in the literature on the feeding value of brown, stack-burned, sun-cured alfalfa hay for dairy cows (*3*) show clearly that such material is decidedly inferior in nutritive value to green alfalfa hay and that this impairment is more or less proportional to the intensity of the brown or black color developed during heating. The similarity of the analytical results obtained in the present study to those for the hay used in the cattle feeding experiment referred to suggests that impairment of the feeding value of the pellets would be of the same order. The melanoidin complexes of carbohydrate and nitrogen not only are apparently refractory to thermal decomposition but also probably represent nitrogen in a nutritionally unavailable form.

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NUTRITIVE VALUE OF RICE

Nutrients in Rice Bran and Rice Polish and Improvement of Protein Quality with Amino Acids

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THE RICE GRAIN, as it is received at the rice mill from the farm thresher, is called rough or paddy rice and is contained in a hard siliceous hull which encloses the edible kernel. It is made up of the hull, the seed coat (pericarp), the starchy endosperm, and the embryo or germ (*15*). The hull is removed in the first step of the milling process and leaves whole brown rice, which retains the bran coat and the germ. The light brown coat is attached firmly to the endosperm or starchy body of the kernel. This coat consists of seven layers of differentiated types of cells and at one end of the kernel lies the germ or embryo, the nutritive value of which has been reported (*4*). The seed coat layers and the embryo contain more than half of the mineral matter of the grain, a fourth of the protein, practically all of the vitamins, and about three fourths of the fat (*12*).

By means of suitable milling equipment rough rice is separated into milled rice, hulls, bran, and polish. The milled or white rice is usually marketed for

The nutritive value of rice bran and rice polish, important by-products of the rice milling industry and extensively used in the feeding of livestock was studied, using the albino rat as the experimental animal. A study was made of the effect on growth and protein efficiency of addition of lysine, threonine, and vitamin B_{12} to rations containing commercial rice bran and rice polish as the only source of protein. Data are also given on amino acid, vitamin, and mineral content of rice bran and rice polish. The results indicate that the proteins of commercial rice and rice polish can be improved by addition of lysine, threonine, and vitamin B_{12}.

human consumption; rice bran and rice polish are important by-products of the milling of rice and are used for the feeding of cattle, sheep, pigs, and chickens, and for the manufacture of rice oil. The oil is largely contained in the germ and about 85% of the entire oil content of the hulled rice goes into the by-products. By extracting fresh rice bran with commercial hexane a crude oil of low free fatty acid content can be obtained. This oil can be refined and bleached by standard methods to give a high grade edible oil. Rice oil contains exceptionally potent antioxidants (*7, 8*). During the process of milling the greater part of the pericarp and the aleurone layers together with the germ (including the scutellum) is removed in the so-called first break bran, which is the first important by-product.

Rice polish is composed of the inner seed coat layer along with some starchy material and is obtained in the later stage of the milling process, a complete description of which is given elsewhere (*6*). Attempts have been made to use rice polish for human consumption (*1*).

The hulls are used in the manufacture of furfural (*14*) and recently its use as roughage in feed concentrates has been studied (*9*).

A good review of the literature on rice bran and oil and rice polish has been given (*7, 8*). These earlier studies dealt with chemical composition of bran and polish and with processing and utilization of rice bran oil. More recent studies have been concerned with the content of some of the essential amino acids (*10, 11*), the more important vitamins (*3*), and biological analysis of the proteins of rice bran and rice polish (*2*).

This paper reports studies on the content of all members of the vitamin B complex, amino acids (including nonessentials), calcium, phosphorus, iron (total and available), and the growth value of the proteins of samples of commercial rice bran and rice polish fed albino rats in diets supplemented with and without additions of lysine, threonine, and vitamin B_{12}.

Experimental Procedure and Results

Commercial samples of rice bran and rice polish were used for the determination of vitamins, minerals, amino acids, and growth value of the proteins.

Tryptophan was released from the sample by enzymatic treatment according to Wooley and Sebrell, as described in detail by Barton-Wright and referred to in previous publications (*4, 5*), which also contain complete references and descriptions for the determinations of vitamins, amino acids, and minerals.

Growth value was determined in studies using albino rats as experimental animals fed rice bran rations containing 8.16% protein and rice polish rations containing 9% protein. Rice bran and rice polish furnished the only surface of protein in these rations, and were fed at levels to incorporate the necessary protein. They were fed with and without 0.2% L-lysine, 0.2% DL-threonine, and 0.1 γ of vitamin B_{12} daily. The composition of the rest of the rations was 4% of Sure's salt mixture No. 1 (*13*), 4% of hydrogenated vegetable shortening, 2% of Cellu flour, 2% of cod liver oil, and 1% of wheat germ oil as sources of vitamins A, D, and E, and the rest as glucose (cerelose). Lysine and threonine were added at the expense of glucose in the ration. The following crystalline components of the vitamin B complex were administered daily to each animal separately from the ration: 25 γ each of thiamine, riboflavin, pyridoxine, and niacin; 150 γ of calcium pantothenate, 3 mg. of *p*-aminobenzoic acid, 6 mg. of Choline chloride, and 1 mg. of inositol.

Table I. Relative Efficiency of Proteins of Rice Bran and Rice Polish with and without Added L-Lysine, DL-Threonine, and Vitamin B_{12}

(Experimental period 10 weeks, 6 males and 6 females in each group. Average results per animal)

Ration	Type of Ration	Gains in Body Weight, G.	Gains in Body Weight, %	Protein Intake, G.	Protein in Rations, %	Protein Efficiency Ratio[a], G.	Protein Efficiency Ratio[a], Increase, %
1	Rice bran	117	...	72.6	8.16	1.61 ± 0.07[b]	...
2	Rice bran + 0.2% L-lysine + 0.2% DL-threonine	135	15.4	76.5	8.16	1.75 ± 0.08	8.7
3	Rice bran + 0.2% L-lysine + 0.2% DL-threonine + 0.1 γ B_{12}	148	27.3[c]	83.0	8.16	1.77 ± 0.05	9.9
4	Rice polish	107	...	58.7	9.00	1.84 ± 0.05	...
5	Rice polish + 0.2% L-lysine + 0.2% DL-threonine	125	16.8[c]	66.1	9.00	1.88 ± 0.06	2.1
6	Rice polish + 0.2% L-lysine + 0.2% DL-threonine + 0.1 γ B_{12}	153	43.0[c]	76.3	9.00	1.98 ± 0.10	7.6

[a] Gains in body weight per gram of protein intake.
[b] Standard deviation of mean.
[c] Significant for $P = 0.05$.

Table II. Determination of Amino Acids

	In Rice Bran (9.1% Protein), %		In Rice Polish (10.4% Protein), %	
	In dry matter	In protein	In dry matter	In protein
Arginine[a]	0.91	10.00	0.83	7.92
Aspartic acid	0.31	3.40	0.50	4.77
Cystine	0.11	1.22	0.15	1.43
Glutamic acid	0.71	7.80	0.76	7.25
Glycine	0.80	8.80	0.88	8.40
Histidine[a]	0.30	3.30	0.39	3.72
Isoleucine[a]	0.48	5.27	0.54	5.15
Leucine[a]	0.70	7.70	0.68	6.49
Lysine[a]	0.56	6.15	0.62	5.92
Methionine[a]	0.34	3.73	0.43	4.10
Phenylalanine[a]	0.44	4.83	0.48	4.58
Proline	0.61	6.70	0.68	6.34
Serine	0.71	7.80	0.77	7.95
Threonine[a]	0.37	4.06	0.39	3.72
Tryptophan[a]	0.36	3.95	0.34	3.24
Tyrosine	0.50	5.49	0.70	6.68
Valine[a]	0.61	6.70	0.63	6.01

[a] Nutritionally essential for the rat.

The animals—six males and six females in each group—were fed ad libitum for 70 days in the growth experiments. Each animal was weighed weekly and accurate weekly records of food consumption were kept. From the gains in body weight per gram of protein intake, the protein efficiency ratios were calculated. The results, expressed as average gain per animal (Table I), indicate that the proteins of rice bran and rice polish can be improved by supplementation with lysine and threonine and a small amount of vitamin B_{12}.

Table III. Vitamins and Other Constituents in Rice Bran and Rice Polish

	Rice Bran, γ/G.	Rice Polish, γ/G.
Thiamine	24.00	22.00
Riboflavin	2.00	2.20
Nicotinic acid	336.00	330.00
Pantothenic acid		
Total	27.70	33.30
Free	11.60	9.90
Biotin	0.60	0.57
Folic acid		
Total	1.46	1.92
Free	0.16	0.18
Pyridoxine	25.00	20.00
Inositol	4627.00	4536.00
Choline	1700.00	1020.00
p-Aminobenzoic acid	0.75	0.73
	%	%
Calcium	1.31	0.91
Phosphorus	1.48	2.44
Iron		
Total	0.019	0.028
Available	0.010	0.012
Nitrogen	1.53	1.76
Protein (nitrogen × 5.95)	9.10	10.47
Fat	13.66	16.40
Moisture	9.80	9.80
Ash	12.00	13.20

Addition of 0.2% L-lysine and 0.2% DL-threonine produced an average gain of 135 grams and a protein efficiency ratio of 1.75 grams in rations containing 8.16% of bran proteins. This is a 15.4% increase in gain and a 8.7% increase in protein efficiency ratio (Table I, rations 1, 2, and 3). Daily addition of 0.1 γ of vitamin B_{12} further increased the gain to 27.3% and the efficiency ratio to 9.9%. Animals fed rice polish protein at the 9% level showed increased gains of 16.8% and a small 2.1% increase in protein efficiency upon supplementation of the ration with 0.2% lysine and 0.2% DL-threonine. Further daily supplementation with 0.1 γ of vitamin B_{12} produced increases in gain up to 43.0% and a small increase in protein efficiency up to 7.6% (Table I, rations 4, 5, and 6). These differences were tested statistically and found to be significant ($P = 0.05$), except for the 15.4% increase with ration 2 and the percentage increases in the protein-efficiency ratios.

The results of these experiments indicate that the proteins of commercial rice bran and rice polish can be further improved by supplementation with lysine and threonine and addition of vitamin B_{12}.

Amino Acid Content. The results of the amino acid determinations expressed percentagewise, calculated on the air-dried samples and also expressed as the percentage in the crude proteins (N × 5.95), are given in Table II. The content of the amino acids (essential) agrees well with that reported elsewhere (*10, 11*).

A number of vitamins were determined by methods referred to elsewhere (*4, 5*). The results of these tests are given in Table III, which also contains data on calcium, phosphorus, iron, and other constituents.

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