The Distribution of Vitamin B_1 in the Rice Grain

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The realization of the importance of the cereal grains as a source of vitamin B_1 in human nutrition has led to a long-standing interest in the way in which the vitamin is distributed between the parts of the grain. This applies particularly to the rice grain in the preparation of which part is rejected, and perhaps more so to the wheat grain which is subjected to a well-developed milling technique, capable of selecting or rejecting fairly closely defined parts of the grain.

The results of a detailed examination of the main component parts of the wheat grain, published recently, have placed on a quantitative basis what was known in a general qualitative way for some time, that the distribution of vitamin B_1 is very far from equal (Hinton, 1947). The endosperm, which, in the sample of wheat examined, was 82·5% of the grain weight, contained only 2·8% of the total vitamin B_1, whereas the scutellum, 1·5% of the grain weight, contained 62% of the total vitamin B_1. The aleurone layer was the other principal contributor, containing 32% of the total. Thus 94% of the vitamin B_1 was contained in sharply defined parts of the grain which amounted to 8·5% of its weight. The concentration of vitamin B_1 in the scutellum was 52 i.u./g., a figure very much higher than any so far known in plants. As a tentative explanation of this distribution it was suggested that the high concentration in the scutellum was a particular example of a normal process in plants, namely, a tendency for vitamin B_1 to concentrate in very young leaves which are in the early stages of differentiation.

The present paper reports the results of a similar examination of two samples of rice.

Structure of the rice grain

The rice grain in general is similar in structure to the other cereal grains (Santos, 1933). The pericarp shows the normal characteristic structures, epidermis, cross-layer, tube cells, etc., each layer being markedly thinner than in wheat. The aleurone layer is one cell in thickness as in wheat, but, in contrast to the latter, the cells have thin walls, and, moreover, extend over the embryo.

The epiblast is more developed than in wheat in which it is greatly suppressed appearing only as a small flap on the surface of the plumule. In rice, however, the epiblast is well developed, fuses at the sides with the scutellum, and envelopes the greater part of the plumule. At the extreme tip the fusion is incomplete and the tip of the coleoptile is exposed. Together with the coleorhiza, to which it fuses at the base, it forms an almost complete covering in which the embryo is embedded (Pl. 1, 1 and 2, and Fig. 1).

The epiblast is considered to be a young modified leaf, thus bearing some analogy to

the scutellum. An examination of the distribution of vitamin B_1 in the rice grain is, therefore, of additional theoretical interest in relation to the explanation suggested above.

EXPERIMENTAL

Material. Two samples drawn from commerce were examined. One, a sample of white rice, had a mixture of varieties and selection of individual grains was necessary to obtain uniform results. The other was a pure sample of a red variety. The grain was hulled by hand to avoid damage to the embryo.

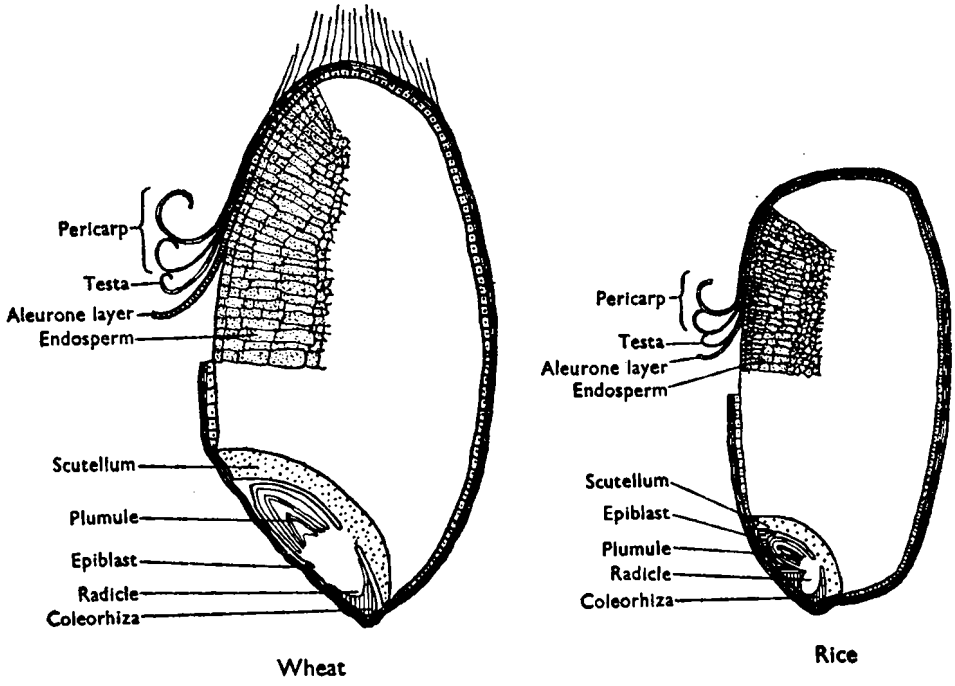
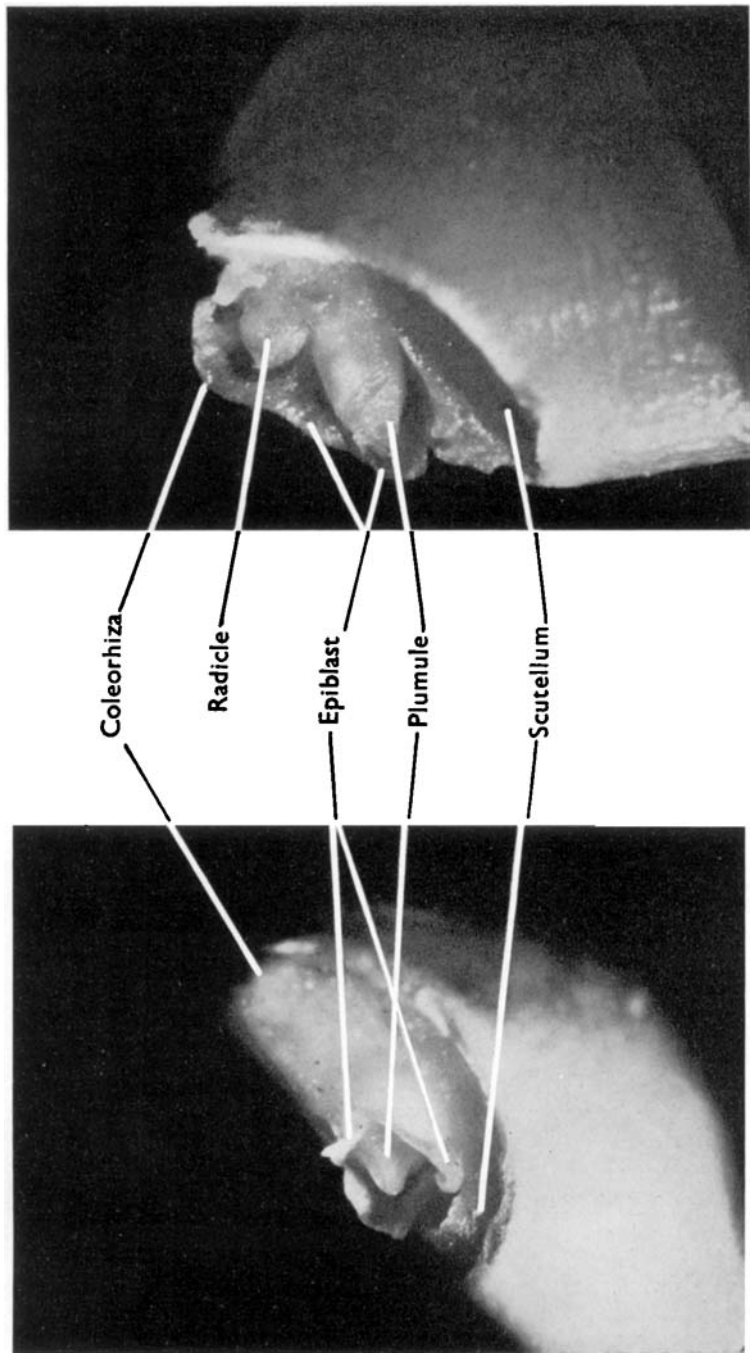


Fig. 1. Comparative diagram of the structure of the wheat grain and of the rice grain.

Dissection. The grain was dissected by hand into its main parts using appropriately shaped needles, micro-knives and other equipment, under a magnification of thirty-six to seventy-two diam. Details of the technique have been described (Hinton, 1947). Dissection presented many difficulties; the endosperm is very brittle, making the grain fragile and difficult to hold; very light pressure in a small pin vice was effective. The pericarp and aleurone layer are very thin and fragile and perfect separation from endosperm could not be obtained. The embryo is extremely small, but a very clean separation of its parts was possible. With the white sample no reliable separation of pericarp from aleurone layer could be effected; with the red sample a partial separation was obtained. The grains were prepared for dissection by placing them for 1–2 days in a moist atmosphere, in which the embryo and aleurone layer absorbed water and became turgid. On dry days, a stream of moist air was directed on to the grains during dissection



2. Dissection of the embryo of the rice grain.

1. Surface view of the embryo of the rice grain.

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to prevent rapid drying. Apart from this the grains received no other treatment and were dissected in the natural state.

The following parts were separated: pericarp (part), aleurone layer, outer endosperm, inner endosperm, covering to the embryo, epiblast, coleorhiza, plumule, radicle, scutellum.

Measurement of vitamin B_1. From 2 to 10 mg. of the vitamin-rich fractions and from 20 to 200 mg. of the endosperm fractions were used for measurement. The vitamin was extracted by action of 0·2N-HCl for 16–24 hr., and the measurement carried out

Table 1. *Vitamin B_1 content of fractions of the rice grain*

Part of grain	Proportion of grain (%)	Vitamin B_1 content (i.u./g.)	Equivalent vitamin B_1 in whole grain (i.u./100 g.)	Proportion of the total Vitamin B_1 of the grain (%)
		Red rice		
Pericarp (part)	1·04	—	—	—
Aleurone + testa	5·2	6·5	33·8	33·7
Covering to germ	0·23	4·1	0·94	—
Epiblast	0·25	7·8	1·96	1·9
Coleorhiza	0·16	10·4	1·66	1·6
Plumule	0·37	8·6	3·18	3·1
Radicle	0·19	15·7	2·98	2·9
Scutellum	1·18	43·6	51·5	50·0
Endosperm	93·8	0·05–0·1	7·0	6·8
Total			103·02	
Vitamin B_1 actually found in whole grain			92·6	
		White rice		
Pericarp + aleurone	5·95	10·5	62·5	35·2
Covering to germ	0·20	4·0	0·8	
Epiblast	0·27	26·0	7·02	3·9
Coleorhiza	0·20	31·5	6·3	3·5
Plumule	0·31	15·5	4·8	2·7
Radicle	0·17	21·5	3·65	2·0
Scutellum	1·25	63·0	78·8	43·9
Outer endosperm	18·80	0·45	8·46	8·8
Inner endosperm	73·10	0·10	7·31	
Total			179·64	
Vitamin B_1 actually found in whole grain			186·0	

by the micro-thiochrome method (Hinton, 1943). As with wheat, enzymic digestion produced no increase in the vitamin B_1 values obtained for any of the fractions, thus suggesting that there was no complication from the presence of cocarboxylase.

RESULTS

The results are expressed on the basis of air-dried material, containing *c.* 12–14% water. Each value is the mean of three or four separate dissections and estimations. They are shown in Table 1. Because of difficulties of dissection, values were not obtained for the pericarp of white rice nor for the subdivision of the endosperm of red rice. There is nothing to suggest that the two samples differ from one another in the composition of these fractions.

DISCUSSION

There was a maximum discrepancy of about 10% between the figures obtained on whole undissected grain and the sum of the figures for the dissected fractions. This is probably mainly an expression of the variation occurring within the main sample, a variation which was also found in the repeat determinations.

In general, the distribution was similar to that found in the wheat grain, the scutellum and aleurone layer accounting for the greater part of the total vitamin B_1. There were, however, minor points of difference. In wheat the scutellum accounted for 62% of the total, in these two rice samples for 44 and 50%. In wheat the endosperm contained 2·8% of the total, in the rice samples 6·3 and 8·8%. Similarly, the embryo of the rice contained a larger proportion of the total, 9·7 and 12·3%, against 2% found in wheat. Thus the distribution in rice was somewhat wider than in wheat.

In rice the continuation of the aleurone layer over the germ was reflected in the vitamin B_1 content of the covering to the germ.

The pericarp was not completely separated, but the whole pericarp and testa would amount to no more than 2% of the grain compared with 8% in wheat, a difference which follows from the greater thickness of the coats of the wheat grain. The aleurone layer similarly amounted to about 4% of the grain weight in rice compared with 7% in wheat, owing partly to the thinner cell walls of the former; this also partly accounted for the greater vitamin B_1 content of this layer in the rice samples, about 8 and 15 i.u./g. as deduced from the experimental results, compared with 5·5 i.u./g. in wheat.

There was a large difference between the total vitamin B_1 contents of the two rice samples. The aleurone layer contained about the same proportion of the total in each sample, but the embryo and the endosperm contained more, and the scutellum proportionately less, in the white sample.

These results therefore show that the high concentration of vitamin B_1 in the scutellum of cereal grains so far examined, namely, wheat, oats, barley, rye, maize (Hinton, 1944), is repeated in the rice grain.

The tentative explanation of this concentration, advanced in the earlier paper, suggested that there is a normal tendency for vitamin B_1 to be concentrated in young leaves still in the process of differentiation. Evidence was quoted from the literature which showed a rising gradient of vitamin B_1 concentration from the oldest to the youngest leaves of a stem. It was then suggested that the scutellum, which is regarded as a modified leaf, becomes, as it were, fixed in a stage of partial differentiation and therefore partakes of this tendency to concentrate vitamin B_1. The unusually high value for this concentration, it was suggested, was the result of several factors, including the relationship of the developing scutellum to the plant which as a whole is approaching senescence and in which available nutrients are being diverted to the grain.

The epiblast is also considered to be a modified leaf; it is made of tissue similar to that of the scutellum, thin-walled parenchyma rich in protein and lipids, and it may therefore have shown a comparable concentration of vitamin B_1. In the two rice samples, where the epiblast amounted to approximately 27% of the embryo weight, reliable figures for the vitamin B_1 content were obtained, but no comparable concentration was found. In the red sample the epiblast had a lower concentration than

the remaining embryo fractions, whereas in the white sample the concentration was somewhat higher than in the plumule and radicle.

It is, perhaps, unwise to draw too close an analogy between epiblast and scutellum. The former can be regarded as a leaf in a morphological sense only. McCall (1934) concludes that its point of divergence from the stem is the procambial plate which corresponds to the first embryonic node and simultaneously separates shoot from root. He suggests that it is therefore the first leaf. Vascular connexion of the leaves with the stem is normally made at the node below which the leaf diverges. As there is no node below the epiblast, it has no vascular connexion and shows no trace of vascular tissue within it. The scutellum diverges at the second embryonic node, is therefore the second leaf and has normal vascular connexions to the first node. Simple vascular strands are seen within it. Thus, whereas the scutellum is correctly described as a modified leaf, the epiblast is no more than a vestigial one, and may have no further resemblance to a leaf than that it occurs at a node.

The results of this investigation into the distribution of vitamin B_1 in the rice grain do not help materially towards understanding the causes of the general pattern of distribution so far found in cereal grains. They do, however, widen considerably the range of vitamin B_1 content found for the embryo. The embryo of the wheat grain appears to be at one extreme with a low vitamin B_1 content and a very small contribution towards the total content of the grain, whereas the rice grain is at the other extreme with a much higher content and a substantial contribution towards the total. It would be of interest to know if there is any further localization of the distribution within the tissue of plumule and radicle in rice, and whether the embryos of wheat and rice reach a comparable stage in their development at the time when the grain ripens and they enter the resting phase.

SUMMARY

1. Two samples of rice, a red variety and a white variety, were dissected into pericarp and testa, aleurone layer, epiblast, coleorhiza, plumule, radicle, scutellum and outer and inner endosperm, and the vitamin B_1 contents of these parts were determined.

2. The scutellum contained 50 and 44%, respectively, of the total vitamin B_1 in the red and white samples, the aleurone layer approximately 33 and 35%, the embryo 9·7 and 12·3% and the endosperm 6·3 and 8·8%.

3. These results are similar to those already reported for the wheat grain about the high concentration of vitamin B_1 in the scutellum and the distribution of the greater proportion of the vitamin between scutellum and aleurone layer. They differ, however, in the higher vitamin B_1 content of endosperm and embryo of rice, resulting in a slightly wider distribution throughout the grain.

4. The epiblast, which is well developed in rice and bears a morphological analogy to the scutellum showed no similar high concentration of vitamin B_1.

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