46. OBSERVATIONS ON THE DISTRIBUTION OF VITAMIN B₁ IN SOME PLANT FAMILIES

By MAGNUS PYKE

From the Research Laboratories, Vitamins Limited, London

(Received 15 January 1940)

THE presence of vitamin B₁, at least in small amounts, appears to be almost universal in higher plants; Schopfer [1936], using as his criterion the growth of *Phycomyces*, detected its presence in the leaves of 134 species of plants. Numerous assays obtained by animal feeding tests on vegetable foodstuffs have also been carried out. The widespread distribution of vitamin B₁ seems to imply that it plays a fundamental part in the metabolism of plants. It was therefore thought to be of interest to investigate from a strictly quantitative basis its incidence in certain important plant families.

The occurrence of vitamin B₁ in the outer integuments and germ of cereal grain is well known. Wheat seeds contain some 100 International Units per 100 g. Bran contains 200–300 and germ 600–2000 i.u. per 100 g. Other grains such as barley, rye and oats contain similar amounts. Outside these species, however, the quantitative distribution of vitamin B₁ is not so well established. The development of a modification of the thiochrome technique by which vitamin B₁ could be conveniently and reliably determined has made it possible to investigate its distribution more closely.

The method which has been adopted in this work has been used successfully on a large number of foodstuffs and the good agreement of the results obtained compared with such published figures as are available appears to establish its reliability.

EXPERIMENTAL

A summary of the method used for the determination of vitamin B₁ is given in Table 1. Fuller details have been published elsewhere [Pyke, 1939]. The results obtained represent the total vitamin present and take no account of whether it occurs in the phosphorylated form as cocarboxylase or in the free state.

Table 1. *Summary of method of determining vitamin B₁*

- (1) *Digestion with pepsin.* 20 g. sample finely minced or ground; made up to 97.4 ml. with 0.1% pepsin in 0.33% HCl; incubated at 37° overnight
- (2) *Digestion with taka-diastase.* 2.6 ml. *N* NaOH added and 100 mg. taka-diastase; incubation continued for a further 5 hr.
- (3) *Oxidation of vitamin B₁ to thiochrome.* Two 3 ml. centrifuged aliquots added to
 - (a) 2 ml. methanol; 1 ml. 30% NaOH; 1% K₃Fe(CN)₆
 - (b) 2 ml. methanol; 1 ml. 30% NaOH

The solutions stirred with N₂; made up to 10 ml. with water; shaken with 13 ml. isobutyl alcohol

- (4) *Measurement of thiochrome.* 10 ml. portions of isobutyl alcohol solutions taken from aliquots (a) and (b) and 1 ml. ethanol added to give clear solutions. The tubes are held side by side in ultraviolet light and standard isobutyl alcohol solution of thiochrome (2 µg. per ml.) added to aliquot (b) until the intensity of its fluorescence matches that of aliquot (a)

The figures from analysis by this method appear to be reproducible within narrow limits. For example, a single cauliflower was finely minced and 10 samples each of 20 g. were separately analysed. The following results were obtained (I.U. per 100 g.) 45, 45, 45, 46, 46, 48, 48, 48, 48, 48. This gives an average of 47 I.U. per 100 g. and a standard deviation of 1.3 I.U., or 3%. In considering any figures for the vitamin B₁ content of plants, it is important to realize that besides possible discrepancies due to the method of analysis, another factor to be considered is the variation in vitamin B₁ content between different samples of the same plant. Three examples are given in Table 2. Except in the case of apples, the variation appears to be quite slight.

Table 2. *Variation in vitamin B₁ content among different samples of the same materials. I.U./100 g.*

Apples		Cauliflower		Potatoes	
Variety unknown	6	Varieties	34	Great Scott, second early	25
James Grieve, dessert	8	unknown	48	Majestic, main crop	27
King Pippin, dessert	15		48	Epicure, first early	29
Miller Seedling, dessert	19		51	Red King, main crop	30
Potts Seedling, cooking	19		53	Variety unknown	30
Quarenden, dessert	19		57		
Warner King, cooking	19				
Worcester Pearmain, dessert	23				

It is interesting now to fit these figures into a wider survey of the vitamin B₁ distribution among the different botanical families within which most of the food plants fall and with which this investigation is primarily concerned. Results are given in Table 3.

Table 3. *Concentrations of vitamin B₁ in plants of different families. I.U./100 g.*

Family	Common name and species	Vitamin B ₁	
		Daniel & Munsell [1937]	Present work
I. Leaves and tops			
Ficoidaceae	New Zealand spinach (<i>Tetragonia expansa</i>)	—	21
Compositae	Endive (<i>Cichorium Endivia</i>)	—	19
	Globe artichoke (<i>Cynara Scolymus</i>)	—	95
	Lettuce (<i>Lactuca sativa</i>)	10-22	23
Cruciferae	Cabbage (<i>Brassica oleracea</i>)	13-22	23
	Cauliflower (<i>Brassica oleracea</i>)	—	50
	Turnip-top (<i>Brassica campestris</i> var.)	19	19
	Seakale (<i>Crambe maritima</i>)	—	27
Polygonaceae	Sorrel dock (<i>Rumex acetosa</i>)	—	25
Umbelliferae	Celery (<i>Apium graveolens</i>)	—	15
	Angelica (<i>Archangelica officinalis</i>)	—	38
	Rock samphire (<i>Crithmum maritimum</i>)	—	48
	Alexanders (<i>Smyrniium Olusatrum</i>)	—	38
II. Roots, bulbs, rhizomes and tubers			
Chenopodiaceae	Beetroot (<i>Beta vulgaris</i>)	—	6
Compositae	Chicory (<i>Cichorium Intybus</i>)	—	25
	Jerusalem artichoke (<i>Helianthus tuberosus</i>)	—	76
Convolvulaceae	Sweet potato (<i>Ipomoea Batatas</i>)	22-23	34
Cruciferae	Radish (<i>Raphanus sativus</i>)	7-9	13
	Swede (<i>Brassica campestris</i> var.)	—	25
	Turnip (<i>Brassica campestris</i> var.)	<12	11
Leguminosae	Tuberous bitter-vetch (<i>Lathyrus montanus</i>)	—	57

Table III (cont.)

		Vitamin B ₁	
Family	Common name and species	Daniel & Munsell [1937]	Present work
II. Roots, bulbs, rhizomes and tubers (<i>cont.</i>)			
Liliaceae	Leek (<i>Allium Ampeloprasum</i>)	18	51
	Onion (<i>Allium Cepa</i>)	5	8
	Ramsons (<i>Allium ursinum</i>)	—	Nil
	Solomon's seal (<i>Polygonatum multiflorum</i>)	—	76
	Spiked Ornithogalum (<i>Ornithogalum pyrenaicum</i>)	—	57
Solanaceae	Potato (<i>Solanum tuberosum</i>)	8-40	30
Umbelliferae	Carrot (<i>Daucus Carota</i>)	6-33	15
	Parsnip (<i>Peucedanum sativum</i>)	26	38
	Angelica (<i>Archangelica officinalis</i>)	—	48
	Alexanders (<i>Smyrniolum Olusatrum</i>)	—	21
III. Seeds and nuts			
Coniferae	Pine kernels (<i>Pinus</i> spp.)	—	162
Cucurbitaceae	Pumpkin, whole seed (<i>Cucurbita maxima</i>)	—	76
Betulaceae	Barcelona nuts (<i>Corylus maxima</i>)	—	38
	Cob nuts (<i>Corylus hybrida</i>)	—	76
Lecythidaceae	Brazil nuts (<i>Bertholletia excelsa</i>)	—	340
Leguminosae	Butter beans (<i>Phaseolus lunatus</i>)	—	140
	Lentils (<i>Lens esculenta</i>)	—	170
	Peanuts (<i>Arachis hypogaea</i>)	73-220	228
	Green peas (<i>Pisum sativum</i>)	17-100	120
Oleaceae	Ash, whole fruit (<i>Fraxinus excelsior</i>)	—	114
IV. Fruit			
Ananaceae	Pineapple (<i>Ananas comosus</i>)	25	10
Cucurbitaceae	Cucumber (<i>Cucumis sativus</i>)	—	15
	Marrow (<i>Cucurbita Pepo</i>)	—	Nil
	Water-melon (<i>Citrullus vulgaris</i>)	—	23
	Rosaceae	Apple (<i>Malus pumila</i>)	3-9
	Pear (<i>Pyrus communis</i>)	2-14	18
	Apricot (<i>Prunus Armeniaca</i>)	9	20
	Damson (<i>Prunus domestica</i> var.)	—	38
	Greengage (<i>Prunus domestica</i> var.)	—	66
	Peach (<i>Prunus persica</i>)	3	6
	Plum (<i>Prunus domestica</i> var.)	—	66
	Blackberry (<i>Rubus</i> sp.)	—	13
	Haws: (<i>Crataegus</i>) green (1 variety)	—	42
	(<i>Crataegus</i>) red (1 variety)	—	19
	Rose hips: red 5 varieties	—	Nil
Rutaceae	Lemon (<i>Citrus Limon</i>)	—	6
	Orange (<i>Citrus sinensis</i>)	33	34
Solanaceae	Tomato (<i>Lycopersicum esculentum</i>)	7-13	15
Vitaceae	Currant	—	10
	Grape	4-11	11
	Raisin	23-35	29
	Sultana	—	29

DISCUSSION

The uniformity of the vitamin B₁ content of leaves and tops is striking. This is perhaps not unexpected if it is assumed, as may well be the case, that vitamin B₁ is synthesized in the leaves and that this synthesis is a side branch of the general metabolism of the plant hinging about the activity of chlorophyll. Be

that as it may, a far greater general uniformity of vitamin B₁ concentration exists in the leaves than elsewhere in the plant.

Turning to the vitamin B₁ content of the parts below ground, while there is little general agreement between different families, a similarity in concentration exists to some extent within each family. In the Liliaceae the differences which appear may be due in part at least to the comparison of different organs. However, in the genus *Allium* the colourless bulbs of *A. Cepa* and *A. ursinum* contain little or no vitamin while the leek contains an appreciable amount, perhaps because it consists of partly expanded leaves with a considerable amount of chlorophyll. The accumulation of the vitamin in a particular organ may be a character of specific or possibly generic value since the colourless bulbs of *Ornithogalum pyrenaicum* contain almost as much as the rhizomes of *Polygonatum multiflorum*. Although, compared with the high values in the Leguminosae, the potato appears to contain little vitamin B₁, nevertheless from the point of view of human nutrition it provides very substantial amounts due to the quantity which can be eaten conveniently.

Although it has not been possible to examine a sufficient number of examples within each family to be able to draw many definite conclusions it seems probable that in most cases the seeds contain the highest proportion of vitamin B₁ in the plant. Also, with the exception of the outstandingly high value of Brazil nuts, representing the Lecythidaceae, legumes appear in general to contain the highest amounts of the vitamin. Indeed the concentration in the seeds of this family is surprisingly uniform. The higher value in peanut and the lower in green pea might logically be attributed to a mere difference in moisture content.

In the case of fruit, the important family of Rosaceae presents an opportunity for speculation. Whereas a green example of *Crataegus* contained 42 I.U. per 100 g., a red sample only showed 19. Rose hips in the red condition, moreover, possessed no vitamin B₁ whatever. It seems possible that this decrease in vitamin B₁ content is due to increasing degrees of ripeness as the climacteric is approached. If this hypothesis is correct it might offer an explanation of the variation in activity of the different varieties of apples examined.

In addition to the figures obtained during the course of this investigation a second column has been included in the table of results made up of figures collected by Daniel & Munsell [1937]. These authorities have collected a very large number of published results. In their paper the figures are given in Sherman units. Conversion factors of either $\frac{1}{2}$ or $\frac{1}{4}$ are suggested for transforming Sherman units into International Units. In the present table Daniel and Munsell's figures have been converted into I.U. by dividing them by three. It will be seen that the thiochrome method used in the present work gives results which compare quite well with these published figures obtained from biological assay.

SUMMARY

1. The vitamin B₁ content of different parts of a number of plants from certain important botanical families has been determined by the thiochrome technique. The results obtained compare favourably with published figures where these are available.

2. In general the vitamin B₁ content is highest in seeds. In most leaves the concentration of vitamin B₁ amounts to a constant value of about 25 I.U. per 100 g., regardless of the botanical family.

3. The possibility is tentatively suggested that variation in vitamin B₁ content of fruits of the Rosaceae is due to the degree of ripeness.

The author wishes to take this opportunity of thanking the Director of the Royal Botanic Gardens, Kew, for providing specimens of plants. He also wishes to acknowledge his indebtedness to Dr R. Melville for his advice and help with the botanical classification.

REFERENCES

- Daniel & Munsell (1937). *Misc. Publ. U.S. Dep. Agric.* no. 275.
Pyke (1939). *J. Soc. chem. Ind.* **58**, 338.
Schopfer (1936). *Arch. Mikrobiol.* **7**, 156.