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TENTATIVE ESTIMATION OF CHLOROPLAST AND NON CHLOROPLAST PROTEINS OF THE LEAVES OF A PLANT BIOMASS

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1. INTRODUCTION

The membranous proteins of lamellae and the soluble proteins of chloroplast stroma account for nearly all the proteins in leaves (Joyard,1979). Agriculture productivity relies on these proteins in different ways. First, the biosynthesis of sugars from carbon dioxide, water and light, depends on them since they are building blocks of the photosynthetic apparatus. Second, they are part of several crops such as vegetables, fodder or leaf protein concentrate ; the quality and value of these crops depend obviously on leaf proteins. It is thus clear that leaf protein composition is an essential data in plant physiology and ecology or in plant breeding and agriculture.
In this communication a model is presented which takes into account RuBPcase turnover number and content in leaves of C_3 and C_4 type plants and relates leaf protein weight to net and gross primary production of a canopy.

2. MODEL DESCRIPTION

The principle of the derivation relating the number N of RuBPcase molecules of a canopy to the carbon weight it may assimilate during a year (CW) has been given by Ellis (1979) :

$$CW = N \cdot \tau \cdot TN \cdot 12 \quad (1)$$

(Abbreviations in table I)

12 is the atomic weight of carbon.

TABLE I. Abbreviations and numerical values

CW : annual gross fixation of carbon by a plant biomass ; for land plants of the Earth, CW is estimated to equal two times the net fixation (Box, 1977), that is $2 \times 53 \cdot 10^{15}$ g (Woodwell, 1978).
LP : leaf protein weight of a plant biomass.
MRuBPcase : molecular weight of RuBPcase, estimated at $5.5 \cdot 10^5$ daltons (Yeoh et al., 1982).
N : number of RuBPcase molecules of a plant biomass.
RuBPcase : ribulose 1,5-bisphosphate carboxylase/oxygenase.
TN : turnover number of RuBPcase ($kat \cdot mole^{-1}$) ; see table III.
ρ : ratio of leaf protein weight to RuBPcase weight in a plant biomass ; see table II.
τ : duration of enzyme activity in one year.
i : index defining an homogeneous type of plant in a specified climatic area.
3 and 4 : indexes corresponding to C_3 and C_4 plants.

For the whole world N may thus be calculated as follows :

$$N = \frac{1}{12} \sum_{1}^{i} \frac{CW_i}{\tau_i \cdot TN_i} \quad (2)$$

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Each i defines an homogeneous type of plant in a specified climatic area. Leaf protein weight is thus given by :

$$LP = \frac{MRuBPcase}{12} \sum_{1}^{i} \frac{CW_i}{\tau_i \cdot TN_i} \rho_i \qquad (3)$$

where it is assumed, according to Yeoh et al. (1982) that RuBPcase molecular weight is rather constant among various plant species. Formula (3) raises nevertheless the question of the choice of plant types and of climatic areas. An example is shown below.

TABLE II. Protein (LP) and RuBPcase content of leaves; DM : dry matter of leaves ; ρ = LP/RuBPcase. (a) : Singer et al. (1952) ; (b) : Pheloung, Brady (1979).

Plant	LP (% DM)	ρ	RuBPcase (% LP)	ref.
C_3 Plants				
Cucumis anguria	28	7	14	a
Lycopersicum esculentum	31	10	10	a
Pisum sativum	25	9	11	a
Xanthium pennsylvanicum	40	11	9.2	a
Triticum aestivum L.	48	7	14	b
Phalaris tuberosa L.	42	6.3	16	b
Bromus uniloïdes H.B.K.	33	8	12	b
C_4 Plants				
Cynodon dactylon L. Pers.	30	22	4.5	b
Chloris gayana Kunth	26	36	2.8	b
Paspalum dilatatum Poir.	27	23	4.3	b
Pennisetum clandestinum Hochst.	26	29	3.4	b

3. LEAF PROTEIN WEIGHT OF THE EARTH LAND PLANTS

In this example, a single climatic area is considered but a distinction is made between C_3 and C_4 plants. Thus :

$$LP = \frac{MRuBPcase}{12 \cdot \tau} \left(\frac{CW_3}{TN_3} \cdot \rho_3 + \frac{CW_4}{TN_4} \cdot \rho_4 \right) \qquad (4)$$

As shown in Tab II, ρ_3 ranges from 6 to 11 and ρ_4 from 22 to 36. ρ_4 is thus about 3 times higher than ρ_3. On the other hand, the turnover number (TN) is limited <u>in vivo</u> by the non saturating carbon dioxide amount (Ellis, 1979 ; Wildner, 1981 ; Tab. III). In fact, this amount is much higher in the bundle sheet cells of C_4 type plants, where RuBPcase works, than in C_3 type plant cells (Ku, 1979). TN_4 is thus clearly higher than TN_3. For these reasons, it is admissible that the ratios ρ_3/TN_3 and ρ_4/TN_4 have similar values. Since $CW_3 + CW_4 = CW$, the relation (4) may be written as follows :

$$LP = \frac{MRuBPcase}{12 \cdot \tau} \; CW \; \frac{\rho_3}{TN_3} \qquad (5)$$

CW, the gross primary fixation, equals at earth scale, about two times the net primary fixation of carbon dioxide by land plants (Box, 1977). The difference between gross and net productivity is accounted for by dark respiration. Dark respiration estimated in various conditions and for numerous plants ranges indeed from 20 to 70 % of gross primary photosynthetic productivity (Kira,1975; Yamaguchi, 1978 ; Ruget, 1981 a and b). Photorespiration is neglected in this estimation.

τ, duration of enzyme activity during a year greatly depends on the plant and on the climatic area. It is estimated to be 0.3 year or $9.5 \cdot 10^6$ sec.

The amount of leaf protein in the land plants of the Earth is thus (data of Tab. I,II and III) :

$$LP = \frac{5.5 \cdot 10^5}{12 \cdot 9.5 \cdot 10^6} \; 2 \cdot 53 \cdot 10^{15} \; \frac{6 \text{ to } 11}{1 \text{ to } 3.3} \text{ g}$$

$$LP = 9.3 \text{ to } 56 \cdot 10^{14} \text{ g}$$

TABLE III. Turnover number (TN) of RuBPcase ($kat.mole^{-1}$), assuming a molecular weight of 550 000 daltons.

Measurement conditions	Plant	TN	Reference
In vitro		18 - 37	Ellis, 1977
"	Spinach	14 - 16	Hall et al., 1981
"	"	17 - 32	Berhow et al., 1982
"	"	8 - 9	Johal,Bourque, 1979
"	Barley	15 - 32	Berhow et al.,1982
Saturating substrate concentrations		17	Ellis, 1979
Natural conditions		3.3	Ellis, 1979
		1 to 3.3	Wildner,1981

4. CONCLUDING REMARKS

The present model of plant productivity allows the connection of data on the amount and turnover number of RuBPcase of photosynthetic apparatus and data on carbon dioxide assimilation by a canopy. Such a model should allow a better understanding of the mechanisms and of the limitations of carbon dioxide assimilation by a canopy. It could also be used as a model for leaf protein productivity.

World production of cereals was $17 \cdot 10^{14}$ g in 1981 (FAO, 1982). Their protein content is about 8% (Demarquilly et al., 1978). World cereal protein production was thus $14 \cdot 10^{13}$ g in 1981. The amount of leaf protein on the Earth is thus about ten times higher than the yearly cereal protein production.

The estimate of leaf protein in a canopy allows the evaluation of other leaf components and specially those of chloroplasts as far as their ratio to leaf proteins is known. Thus the world amount of RuBPcase may be evaluated assuming either a C_3 type or a C_4 type carbon dioxide assimilation. According to the above estimation of leaf proteins and to the data of table II, the estimate ranges from 8.6 to $90 \cdot 10^{13}$ g for a C_3 type or from 2.6 to$25 \cdot 10^{13}$ g for a C_4 type. These values are higher than the $4 \cdot 10^{13}$ g computed by Ellis (1979) who used net instead of gross primary productivity and estimated τ at 0.5 year (Personal communication).

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