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The Quality of Soybean Protein as Tested in Children

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INTRODUCTION

Soybeans constitute without any doubt, one of the most outstanding world resources of protein. Its potential significance to world nutrition, however, did not happen by chance. The particular characteristics of soybean protein made it possible for food scientists and technologists to utilize and transform them into a variety of products of increasing acceptance by the human population. Although acceptance is probably one of the principal characteristics a food must have, as important and of great significance is the nutritional quality it may have. In this particular respect, soybean protein is also interesting, which even though deficient in the essential sulfur amino acids, is of a relatively high quality.

Many soybean protein–based products have appeared in the food market and more will become available in future years. Together with these foods, interest has also developed to test the protein quality of such products, because of the need – more important every day – to develop, produce and market food products with the highest quality possible.

The present manuscript summarizes work carried out on the protein quality evaluation in young human subjects of soybean protein. The first part deals with soybean protein as the sole source of protein and the second, with soybean protein as part of a food system.

STUDIES WITH SOYBEAN AS THE SOLE SOURCE OF PROTEIN

a. As a milk substitute in infants and malnourished children

Among the first studies carried out in young human subjects are those of Fomon (1). In his studies groups of small children were fed human milk at an intake which varied from 200 to about 300 mg N/kg/day, as well as cow's milk at intakes from about 280 to 450 mg N/kg/day, and a milk made from soybean flour at an intake that varied from 220 to 380 mg/kg/day. The effect of feeding these levels of nitrogen from the three sources was measured by the nitrogen balance technique which measures the amount of N retained by substracting from the known intake those losses of N taking place in feces and urine. The results are shown in Figure 1. The Figure shows higher nitrogen retention values as protein intake increases, which is the type of response to be expected. It is of interest to point out that the nitrogen retention values from the soybean flour formula fed at similar levels as those of the two other protein sources fall within the same area, suggesting the protein quality of these food to be similar.

Protein quality evaluations of various protein sources were reported by De Maeyer and Vanderborght (2). The proteins were human and cow's milk, two soybean flour products, sesame, peanut and cottonseed flours. The method used was the nitrogen balance index, which consists in feeding various levels of protein and measuring at each level the nitrogen balance. The evaluation of the quality of protein is calculated by regression analysis of nitrogen intake on nitrogen retention. The results obtained are shown in Table 1. The coefficients of regression are equivalent to biological value. The two soybean products were slightly below the value for cow's milk with the toasted soy product of lower quality than the soy milk. This shows the effects of processing causing some damage to the proteins. The results also show that among vegetable proteins, the soybean is the best.

The quality of soy milk protein in comparison with cow's milk protein was reported by Dutra de Oliveira et al. (3), using protein-malnourished children with and without clinical edema. Nitrogen intake for soy protein in one case ranged from 251-920 mg/kg/day and from 427 to 1182 mg in the second. For milk, nitrogen intake was from 316 to 1008 in one case and from 365 to 978 mg N/kg/day. Evaluation of quality was performed by nitrogen balance and the results are presented in Figure 2. Higher average values were found for soy milk when the children had clinical edema at admission; the opposite was true for the group without clinical edema at admission. It is difficult to evaluate these results because of the condition of the children used, and because intake of protein was too high. The method used loses sensitivity when nitrogen intake reaches high levels, where the response is curvilinear rather than straight, which is the case at lower nitrogen intakes.

The results of these investigators, as well as that of others (4, 5, 6, 7) in which soybean protein has been the only protein source for infants and young children, indicate it has a protein value of 80% that of milk proteins, and that these soy-based and soy protein-based infant formulas satisfactorily support the growth and development of infants.

b. Protein quality in children aged 8 – 12 years

Studies on the quality of soy protein in older children have been reported by a few investigators. Parthasarathy et al. (8) fed children aged 8 – 9 years old with 1.2 g of protein from cooked whole soybeans, per kg body weight per day, with and without methionine supplementation, and the results were compared to nitrogen balance obtained from milk protein feeding at the same level of intake. The results of the study are summarized in Table 2. The nitrogen balance data obtained were converted into biological value, which represents the amount of the absorbed nitrogen retained by the organism. The value for soy was 63.5% which was improved to 74.9% upon the addition of methionine. This results were expected because of the known deficiency of sulfur amino acids in soy protein. The value for milk proteins was 82.6%. Accordingly, soybean protein for children of the age used has a value of 77% that of milk.

The beneficial effect of methionine supplementation of soybean protein tested in children was also reported by Graham (10). Some of his results are shown in Table 3. The data demonstrate that at the intakes tested soy protein in children is definitely improved by supplementation with methionine.

Using older children 12-16 years old, Korslund et al. (10) fed them with 4 g of N of Texturized Vegetable Protein from soybeans with and without the addition of methionine. As reference protein, they utilized beef fed at the same level of intake, that is 4 g N/kg/day.

The results obtained are shown in Table 4. At the low level of intake of 4 g of N, nitrogen balance of the subjects was negative. The addition of methionine, however, increased nitrogen retention to values somewhat above those observed with beef. These results then indicate that at low levels of intake soy protein as TVP is lower in quality than beef, however, it is improved substantially by supplementation with methionine.

AS A PROTEIN SUPPLEMENT

The protein quality of soybean is quite good, however, its greatest value is when used in combination with other foods particularly cereal grain protein. There are various studies performed in children fed soybean protein-based foods. De Maeyer and Vanderborght (12), using 3-7 month old children recovering from protein malnutrition demonstrated that soybean protein caused lower nitrogen retention than protein from cow's milk. This observation is shown in Table 5. The regression coefficient for milk protein was 0.71 while that from soybean flour was 0.53. In these studies the proteins provided from 64.2 to 88.5% of the total N intake for milk, and from 66.8 to 86.7% of the total N intake for soybeans. The rest of the nitrogen was provided mainly by rice fed in a basic diet. The authors indicated that the lower value for soybean was probably due to improper processing. It is more likely, however, that children on milk were more protein depleted than those on soy, influencing the results in favor of milk.

The results of other studies along these lines have been reported by other workers. Huang et al. (12) presented results obtained from 9 children of a total of 57 in whom the evaluation of soybean protein was measured using nitrogen balance. The food intake of the children was made of a mixture of 45% soybean,.15% rice, 10% oil, 27.5% sucrose and 2.5% mineral mixture. This mixture was tested on four children and 3 on milk, to serve as reference. Two soybean products were used, a full-fat soy and a soybean flour. The results are shown in Table 6.

Protein intake varied between 3.5 and 3.7 g/kg/day with an adequate energy intake. Nitrogen retention expressed in absolute terms or as percentage of the intake, was essentially the same between the two types of soybean products used, as well as with the results from milk. The digestibility of the protein was high in all cases, however, it was higher for milk proteins. Table 6 shows also the PER of the two soybean products and of milk, as measured in the 57 children selected for the study. The values correlate very well with the nitrogen balances measured.

Similar results were reported by Dutra de Oliveira et al. (13, 14) who fed children a food made of 19.5% soybean, 4.5% milk solids and 76% corn flour. The results of his studies are presented in Table 7. The intake of the soybean food was 1.98 g/kg/day while that from milk was 2.38 g. This difference in intake explains the difference in nitrogen retention in favor of milk. The value from the soybean food, however, is quite acceptable. Bressani et al. (15) reported on the quality of a food mixture containing 38% soybean flour and 58% corn flour. The mixture was evaluated in children by the nitrogen balance method. The results are presented also in Table 7. These results present similar retention values for the two protein sources. The one aspect that merits attention is the lower digestibility of the soybean foods, which as indicated before is lower than those from milk.

The mixture tested by Bressani et al. (15) was compared with other foods of vegetable and animal origin. In this case the method used was the nitrogen balance index, which consists in feeding the protein at various levels of intake and calculating the quality by regression analysis. These results are shown in Table 8. The coefficient of regression show the soybean product to be about 90% the value of milk.

Other types of foods containing soy protein have also been tested in children. A simulated ground beef product containing 28.8% soybean fibrils was tested in children by Bressani et al. (16). The method used for evaluation was the nitrogen balance index, and a summary of the results are shown in Table 9. The Table shows also the regression of nitrogen absorbed on nitrogen balance with a coefficient of 0.53 which is equivalent to about 80% of the value of milk protein as reported previously.

The effect of increasing the protein quality of cereal grains by small additions of soybean flour have been also tested in children. Some results from our laboratory are summarized in Table 10. In this case, feeding of corn alone gave a nitrogen retention value of 30 mg which was increased to 63 mg when the corn flour was supplemented with 8% soybean flour. This Figure is slightly below that obtained from milk protein when fed at similar levels of intake (17).

These results demonstrate, therefore, the relatively high value of soybean protein, good by itself, but much better when incorporated with other foods particularly cereal grains.

Table 11 summarizes the results of various investigators using different soybean-containing foods as compared to milk. The results are expressed as percentage of nitrogen intake. They clearly show that all these soybean-containing foods have a protein quality which is similar to the quality of milk proteins.

CONCLUSIONS

The present document reviewed a series of reports dealing with the protein quality of soybean protein, in young human subjects, when it provided the only source of protein or when it was part of a food.

The results of protein quality evaluation when soybean provided the entire intake of protein indicate its quality to be below that of milk proteins used as reference, however, slight supplementation with methionine increased its quality to almost that of milk. An additional finding was its lower digestibility.

Soybean protein is used more advantageously in nutrition when it constitutes part of a food, particularly, when combined with cereal grains. The results of various investigators have demonstrated such foods to be of excellent nutritional value for young human subjects. It is safe to suggest that efforts should be made to incorporate such a protein into food systems, particularly those based on cereal grains.

REFERENCES

1. Fomon, S.J. Comparative study of human milk and a soybean formula in promoting growth and nitrogen retention by infants. *Pediatrics 24*:577-584, 1959.
2. De Maeyer, E. M. and H. L. Vanderborght. Determination of the Nutritional Value of Different Protein Foods in the Feeding of African Children. p. 143-155. In: meeting Protein Needs of Infants and Children. Pub. 843. NAS/NRC. Washington, D. C. 1961.
3. Dutra de Oliveira, J. E., L. Scatena, N. de Oliveira Netto and G. G. Duarte. The nutritive value of soya milk and cow's milk in malnourished children. A comparative study. *Tropical Ped. 69*:670-675, 1966.
4. Cowan, C. C.; R. C. Brownlee, W. R. DeLoache, H. P. Jackson and J. P. Matthews. *South Med. J. 61*:389-393, 1969.
5. Omans, W. B.; W. Leuterer and P. Gyorgy. *J. Pediatrics 62*:90-106, 1963.
6. Graham, G. G.; R. P. Placko, E. Morales, G. Acevedo and A. Cordano. *Am. J. Dis. Child. 120*:419, 1970.
7. Dean, M. E. *Med. J. Aust. 1*:1289-1293, 1973.
8. Parthasarathy, H. N.; T. R. Doraiswamy, M. Panemangalore, M. Narayana Rao, B. S. Chandraseckar, M. Swaminathan, A. Srinivasan and V. Subrahmanyan. The effect of fortification of processed soya flour with DL-methionine on the digestibility, biological value and net protein utilization of the proteins as studied in children. *J. Biochem. 42*:377-384, 1964.
9. Graham, G. G.; Methionine or lysine fortification of dietary protein for infants and small children. *In*: Amino acid Fortification of Protein Foods. N. S. Scrimshaw and A. M. Altschul (Editors). Cambridge, Mass. The MIT Press, 1971. p. 222-236.

10. Korslund, M.; C. Kies and H. M. Fox. Comparison of the protein nutritional value of TVP, methionine-enriched TVP, on adolescent boys. *J. Food Sci. 38*:637-638, 1973.
11. De Maeyer, E. M. and H. Vanderborght. A study of the nutritive value of protein from different sources in the feeding of African children. *J. Nutr. 65*:335-352, 1958.
12. Huang, P.; T. Tung, M. Lee and H. Wei. Feeding of infants with full-fat soybean in foods. In: Proceedings International Conference in Soybean Protein Foods. Peoria, Ill. Oct. 17-19, 1966. p. 183-194. ARS/USDA Pub. No. 71-35.
13. Dutra de Oliveira, J. E.; N. De Souza, T. A. de Rezende, L. A. Valiente, V. F. Boyd and E. E. Doggy. Development of a food mixture for infants and young children in Brazil. *J. Food Sci. 32*:131-135, 1967.
14. Dutra de Oliveira, J. E. and N. de Souza. Metabolic studies with a corn and soya mixture for infant feeding. *Arch. Latinoamer. Nutr. 17*:197-206, 1967.
15. Bressani, R.; F. Viteri, D. Wilson and J. Alvarado. The quality of various animal and vegetable proteins with a note in the endogenous and fecal nitrogen excretion of children. *Arch. Latinoamer. Nutr. 22*:227-241, 1972.
16. Bressani, R.; F. Viteri, L. G. Elias, S. de Zaghi, J. Alvarado and A. D. Odell. Protein quality of a soybean protein textured food in experimental animals and children. *J. Nutr. 93*:349-360, 1967.
17. Viteri, F. E.; C. Martinez and R. Bressani. Evaluacion en ninos de la calidad proteinica del maiz comun, del maiz Opaco-2 y del maiz comun suplementado con aminoacidos y otras fuentes de proteina. En: Mejoramiento Nutricional del Maiz. R. Bressani, J. E. Braham y M. Behar (Editores). Publicacion INCAP L-3 1972. p. 195-208.

TABLE 1

Protein Quality of Various Protein Sources as Tested in Children *1/*

Protein source	Regression NR to NI	Value of NI for NR = 0 mg/kg/day
Human milk	NR = −75 + 0.93 (NI)	81
Cow's milk	NR = −70 + 0.75 (NI)	94
Saridele Toffaroma	NR = −65 + 0.74 (NI)	88
Toasted soy	NR = −64 + 0.69 (NI)	93
Sesame flour	NR = −91 + 0.50 (NI)	181
Peanut flour	NR = 103 + 0.55 (NI)	186
Cottonseed flour	NR = −52 + 0.36 (NI)	145

1/ De maeyer and Vanderborght (1961)
2/ Soybean milk.

TABLE 2

Protein Quality of Soybean Fed to Children from 8 to 9 years of age

Protein source	Protein intake g/kg/day	True protein digestibility %	Biologic value, %
Soybean flour	1.2	84.0	63.5
Soybean flour + DL-Methionine	1.2	86.4	79.9
Skim milk	1.2	87.1	82.6

Parthasarathy et al. (1964).

TABLE 3

Effect of Methionine Supplementation of Soy Milk in Children[1]

Protein	DL-Met mg/kg/dat	Child age, m.	Nitrogen Intake	Nitrogen Retained
			mg/kg day	
Sobee	–	21	240	42
Sobee	11		232	70
Sobee	–	23	194	23
Sobee	14		198	54

1/ Graham (1969).

TABLE 4

Protein Quality of Soybean Fed to young adults from 12 to 16 years of age

Protein source	Nitrogen intake g/day	Apparent digestibility %	Nitrogen balance g/day
Soybean protein (TVP)	4.0	79	−0.08
Soybean protein (TVP) + 1% DL-Met	4.0	80	+0.48
Meat	4.0	82	+0.32

TVP = Textured Vegetable Protein
Korslund et al. (1964).

TABLE 5

Protein Quality of various Protein sources as Supplements to a Basic Diet of African Children[1,2]

Protein	Regression of nitrogen absorbed to nitrogen balance
Milk	NB = −106 + 0.782 (NA)
Peanut/Beans	NB = −128 + 0.716 (NA)
Peanut	NB = −103 + 0.653 (NA)
Soy flour	NB = −106 + 0.619 (NA)

[1]/ De Maeyer and Vanderborght (1961)
[2]/ Based diet: Rice, Banana bread, oil sugar, orange.

TABLE 6

Nitrogen Balance of Small Children Fed Soy Protein as the Main Protein Component in Soybean and Rice Based Rations

Protein source	Average age, days	Average weight, g	PER	Intake	Nitr. balance mg/kg/day Total Excretion (Urine + feces)	Retention	Protein Digestibility (apparent), g %
Whole soy bean flour*	264	8,652	0.42	567	432	135(23.8)	83.5
Whole soy bean flour**	286	8,913	0.42	590	446	144(24.4)	82.2
Milk	293	8,328	0.49	582	437	145(24.9)	88.7

* Soybean flour toasted. Formula: Soybean product 45%, Rice flour 15%, Soybean oil 10%, Sucrose 27.5%, Salt mixture 2.5%

** Obtained by extrusion.
Huang et al. (1967).

TABLE 7

Nitrogen Balance Index in Children Fed with Rich Protein Foods prepared with Soybean Flour

Protein food	Protein intake g/kg/day	Nitrogen Absorbed Intake, %	Retained	Reference
Children food	1.98	72.7	23.8	Dutra de Oliveira et al (1967)
Milk	2.38	80.1	30.3	
Incaparina No. 14	2.17	75.5	27.1	Bressani et al. (1972)
Milk	2.41	88.6	21.5	

TABLE 8

Protein Quality of various Vegetable Protein Mixtures Tested in Children[1]

Protein	Regression of nitrogen absorbed to nitrogen balance
Milk	NB = –33 + 0.69 (NA)
Soy/Corn (38/58)	NB = – 39 + 0.63 (NA)
Soy/Cottonseed/Corn (19/19/58)	NB = –39 + 0.53 (NA)
Cottonseed/Corn (38/58)	NB = –30 + 0.50 (NA)
Egg	NB = –43 + 0.64 (NA)

[1]/ Bressani et al. (1972).

TABLE 9

Nitrogen Balance of Children Fed a Soybean Protein Textured Food[1]

Nitrogen, mg/kg/day Intake	Absorbed	Retained
231 ± 14	190 ± 11	49 ± 10
156 ± 7	120 ± 15	9 ± 16
114 ± 10	82 ± 12	–10 ± 9
78 ± 3	48 ± 7	–27 ± 16
0		–85
TVP	NR = –45 + 0.53 (NA)	
Milk	NR = –33 + 0.69 (NA)	

[1]/ Bressani et al. (1967).

TABLE 10

Protein Quality of Lime-Treated Corn Supplemented with Soybeans Fed to Preschool Children

Protein source	No. of Children	Chronologic age, months	Nitrogen Balance		
			Intake	Absorbed	Retained
			mg/kg/day		
Corn	6	30	192	144	30
Corn + soybean supplement	6	30	197	154	63
Milk	7	24	195	157	75

Viteri et al. (1972).

TABLE 11

Summary of Results of various Studies on the Evaluation of Soybean Protein or Products in Children

Study	Soy food	Nitrogen Retention % of intake[1]	
		Soy	Milk
Huang et al. (1967)	Soy/Rice	23.8 24.4	24.9
Dutra et al. (1967)	Soy/Corn	23.8	30.3
Dutra & De Souza (1967)	Soy/Mixed Diet	25.5	19.7
Bressani et al. (1972)	Soy/Corn	27.1	21.5
Bressani et al. (1967)	Soy Text. Food	26.6	23.4
Viteri et al. (1972)	Corn (92)/Soy (8)	32.0	38.4

[1]/ The intake for both sources was practically the same within studies but not necessarily the same between studies.

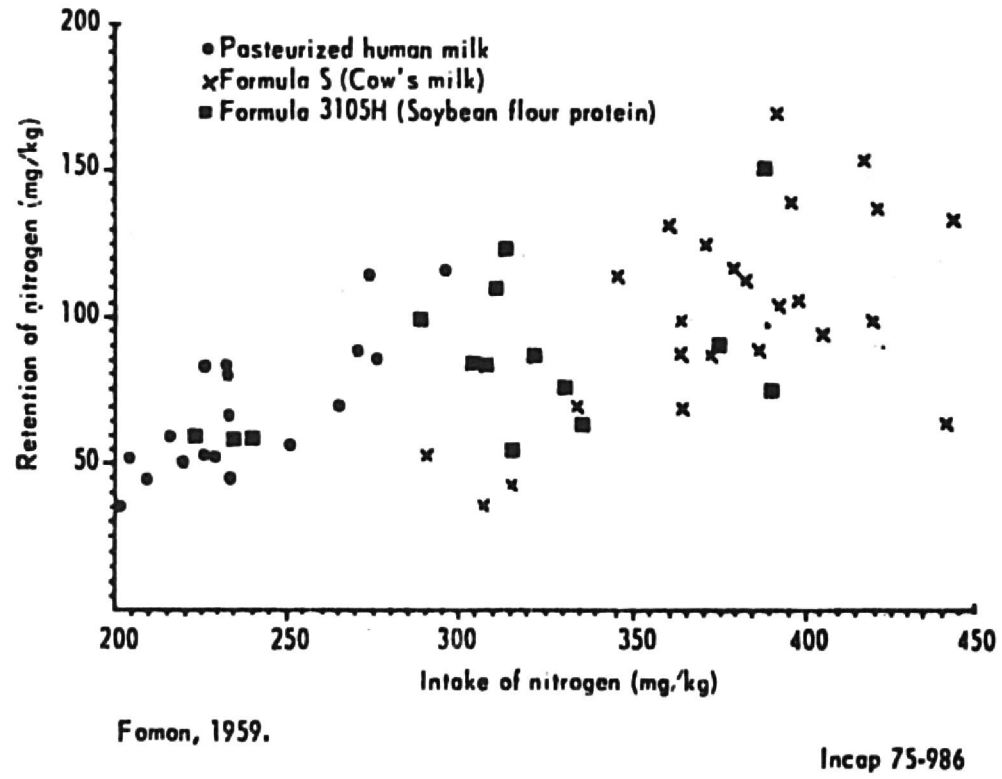

Figure 1. Nitrogen retention values with increasing intake of protein.

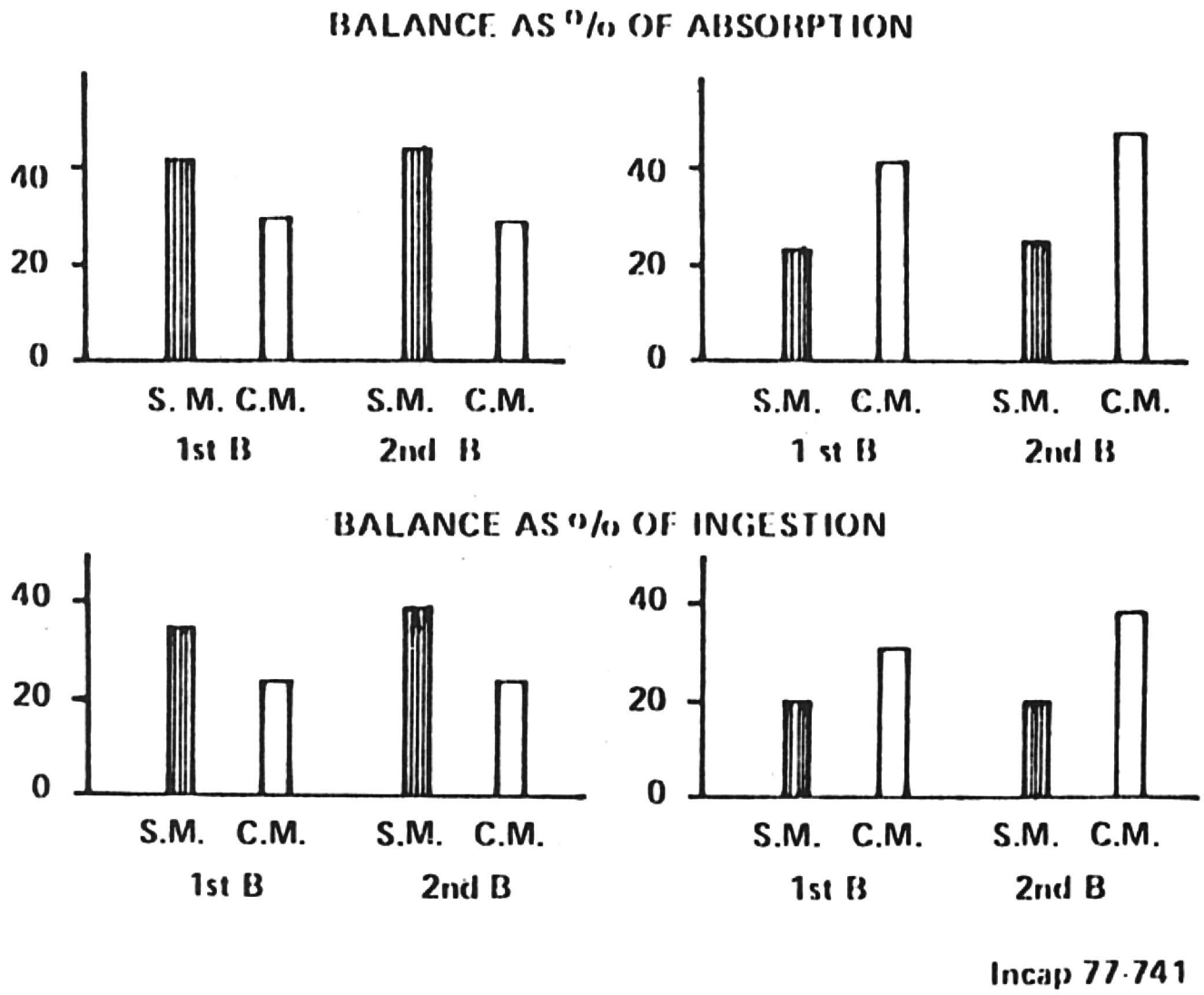

Figure 2. Nitrogen absorption and balance in children fed soya milk and cow's milk. Data include results of the first and