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Chemical Composition and Protein Quality of Newly Released Groundnut (*Arachis hypogaea* L) Cultivars*

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Abstract: Five groundnut (*Arachis hypogaea* L) cultivars developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and two local cultivars as controls were grown in post-rainy and rainy seasons at Patancheru, India. They were analysed for their proximate composition, minerals and trace elements, amino acid composition, true protein digestibility (TD), biological value (BV), net protein utilisation (NPU), and protein efficiency ratio. One-hundred seed mass, protein content and TD were significantly higher in the post-rainy season while starch, sugars, BV and NPU were significantly higher in the rainy season. Post-rainy cultivars exhibited higher concentrations of potassium, calcium, iron and several essential and non-essential amino acids. TD of blanched groundnut was better than that of the whole seeds. The composition and protein quality of ICRISAT cultivars were comparable to those of the controls.

Key words: groundnut, season, whole seed, blanched, chemical composition, minerals and trace elements, amino acid composition, true digestibility, net protein utilisation, biological value.

INTRODUCTION

Groundnut (*Arachis hypogaea* L) is an important source of protein (average content 26%). Because of its high oil content (average oil 44%), it is also an important source of energy for millions of people living in the semi-arid tropical regions. India and China are the largest producers of groundnut in the world. In India, groundnut is grown in both the rainy and post-rainy seasons. Groundnut quality and physicochemical properties have been described by Cobb and Johnson (1973) and Ahmed and Pattee (1987). However, there is little information on quality parameters of groundnut obtained from the rainy (July–October) and post-rainy (December–April) seasons. The groundnut research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) aims to improve not only the production and productivity of groundnut but also its nutritional quality. Recently several groundnut cultivars developed by ICRISAT have been released for cultivation in India and elsewhere (ICRISAT 1991). However, there are no published papers describing the nutritional quality of these cultivars so as to provide a comparison with the already established cultivars that have been grown for several years. In this paper we report the variability in components of nutritional quality of five ICRISAT groundnut cultivars grown in the rainy and post-rainy seasons, and compare them with two cultivars that have been grown extensively in India.

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MATERIALS AND METHODS

Materials

Five groundnut cultivars, ICGS 1 (ICGV 87119), ICGS 5 (ICGV 87121), ICGS 11 (ICGV 87123), ICGS 21 (ICGV 87124) and ICGS 44 (ICGV 87128), were grown during the 1985/86 post-rainy and 1988 rainy seasons at ICRISAT Center, Patancheru, India. Two other cultivars, Kadiri 3 (Robut 33-1) and J 11, which have been cultivated extensively in India over several years, were also grown as controls along with the ICRISAT cultivars. After harvest, seed samples were stored at 4°C before analysis.

In both the seasons, groundnut cultivars were grown on Alfisols with 60 kg ha $^{-1}$ P_2O_5 as a basal fertiliser dose under irrigated conditions. During the 1985/86 post-rainy season, the temperature ranged from 17·5 to 31·9°C with a mean of 24·7°C. Relative humidity ranged from 31·8 to 77·9% with a mean of 54·9%, and there were 140 mm of rainfall. During the rainy season of 1988, the temperature ranged from 21·8 to 29·7°C with a mean of 25·8°C. Relative humidity ranged from 63·3 to 91·8% with a mean of 77·6%, and there were 778 mm of rainfall. A blanched sample was obtained by removing the seed coat manually.

METHODS

Chemical composition

Nitrogen content was determined using a Technicon auto analyzer (Singh and Jambunathan 1980). A factor of 5·46 was used for converting the nitrogen into crude protein content. Oil was determined by extracting groundnut meal with *n*-hexane in a Soxhlet apparatus. Starch was hydrolysed using amyloglucosidase enzyme (Sigma) and determined according to Thivend *et al* (1972). Total soluble sugars in groundnut meal were extracted with hot aqueous ethanol and determined according to Dubois *et al* (1956). Ash and crude fibre contents were determined according to the method of the Association of Official Analytical Chemists (AOAC 1984).

Determination of minerals and trace elements

Minerals and trace elements were analysed according to the method of AOAC (1984) on defatted samples. The wet digestion method was followed for phosphorus content and the dry ashing method for the analysis of other elements.

Three determinations were made for the chemical composition, minerals and trace elements, and mean values are reported. Moisture content was determined by drying the groundnut meal at 110°C for 16 h in a forced draught oven, and all results are expressed on a dry weight basis.

Amino acid determination

Fifty milligrams of the defatted meal were hydrolysed with 50 ml of 6 M HCl by refluxing for 24 h. The acid was removed in a rotary flash evaporator. The residue was washed with water and the procedure was repeated thrice to remove traces of acid and dried. The residue was dissolved in 9 ml of 0·2 M sodium citrate buffer (pH 2·2), followed by the addition of 1 ml of 5 μM ml^{-1} norleucine (internal standard) and then filtered. One hundred μl of the filtrate was used for amino acid analysis (Beckman 119-CL). Tryptophan was not determined. Two determinations were made, and mean values are reported.

Rat bioassay

True protein digestibility (TD), biological value (BV), net protein utilisation (NPU), utilisable protein (UP), and protein efficiency ratio (PER) were determined using Wistar strain male rats (Indian Drugs and Pharmaceuticals Limited, Hyderabad). Casein (Animal Nutrition Research Council Reference Casein, Sheffield Chemical Company, Union, New Jersey, USA) was used as the reference standard. Studies on a few groundnut cultivars from the 1988 rainy season were conducted on blanched and whole seeds under identical conditions to investigate the effect of seed coat on nitrogen utilisation.

For the determination of TD, BV and NPU in each diet, groups of five Wistar male rats, each weighing about 70 g, were used. Each rat was daily fed a 10-g diet (dry weight basis) containing 150 mg nitrogen. At the end of the experimental period of 5 days, the remaining unconsumed diet was recorded and total nitrogen intake was determined. TD, BV, NPU and UP were calculated according to Eggum (1973). For the determination of PER, groups of 10 male rats, each weighing about 35 g, were used. The diet consisted of test material contributing 10% protein in the diet, 4% mineral mixture, 1% vitamin mixture, 10% fat, 5% cellulose and corn starch to make up the remaining diet. The experiment was conducted for 28 days (Pellett and Young 1980).

We used the Duncan's Multiple Range Test (SAS 1985) to analyse the data, and significant differences obtained are discussed in the text.

RESULTS AND DISCUSSION

Chemical composition

Results of analyses of groundnut cultivars grown in the post-rainy season 1985/86 and rainy season 1988 are shown in Table 1. Data obtained in the 1985/86 post-

TABLE 1
Chemical composition of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Center[a]

Cultivar	*Season*	*Protein*	*Oil*	*Starch*	*Sugars*	*Fibre*	*Ash*	*100-seed mass* (g)
				(%)				
ICGS 1	PR	26·5	51·3	12·5	4·9	2·3	2·4	56·2
	R	21·7	52·4	15·1	6·2	2·4	2·6	37·0
ICGS 5	PR	26·9	50·5	12·9	4·8	2·4	2·4	60·7
	R	22·5	50·9	14·7	6·6	2·8	2·8	37·0
ICGS 11	PR	26·5	51·3	12·5	4·9	2·4	2·4	57·3
	R	22·5	51·1	14·5	6·2	2·7	2·6	37·2
ICGS 21	PR	25·5	52·7	11·9	5·3	2·1	2·4	69·3
	R	20·0	52·8	14·8	6·1	2·7	2·6	43·8
ICGS 44	PR	26·6	51·5	12·8	4·6	2·2	2·3	63·1
	R	21·5	52·4	14·3	6·3	2·4	2·6	36·4
Controls								
Kadiri 3	PR	30·8	49·0	11·8	3·6	2·2	2·3	48·1
	R	21·0	50·0	16·3	7·0	2·6	2·7	40·0
J 11	PR	26·8	49·0	14·2	5·4	2·2	2·5	31·0
	R	22·0	50·5	15·2	6·4	2·6	2·7	26·2
SE±	PR	0·64	0·52	0·30	0·22	0·04	0·03	4·71
	R	0·33	0·41	0·25	0·12	0·06	0·03	2·01

[a] Means of three determinations, dry weight basis.
PR = Post-rainy season 1985/86, R = rainy season 1988.

TABLE 2
Mineral and trace element composition (mg per 100 g) of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Center[a]

Cultivar	*Season*	*Phosphorus*	*Potassium*	*Calcium*	*Magnesium*	*Zinc*	*Copper*	*Iron*	*Manganese*
ICGS 1	PR	405	700	95	212	2·9	0·8	5·9	1·1
	R	345	512	62	197	3·2	0·8	4·3	1·1
ICGS 5	PR	400	685	86	207	2·8	0·9	7·5	1·2
	R	352	530	53	211	3·0	0·8	4·7	1·2
ICGS 11	PR	405	660	93	204	2·9	0·8	5·3	1·2
	R	357	525	74	202	3·1	0·8	3·8	1·1
ICGS 21	PR	392	637	75	193	2·8	0·9	4·7	0·9
	R	366	514	52	201	3·2	0·8	4·4	1·3
ICGS 44	PR	390	631	92	191	2·7	0·8	6·0	1·1
	R	345	513	63	195	2·9	0·7	5·1	1·3
Controls									
Kadiri 3	PR	398	678	79	201	2·6	0·8	5·9	0·9
	R	550	600	58	189	3·5	0·9	4·1	1·3
J 11	PR	420	688	75	211	2·7	0·8	4·6	1·2
	R	370	538	67	206	3·2	0·8	3·6	1·0
SE±	PR	3·8	10·0	3·3	3·1	0·04	0·01	0·37	0·05
	R	28·0	11·7	2·9	4·4	0·08	0·02	0·19	0·04
Recommended dietary allowance[b]		800	—	800	350	15	2–3	10	2·5–5·0

[a] Means of three determinations, dry weight basis.
[b] Recommended dietary allowance for an adult male, National Academy of Sciences (1980).
PR = Post-rainy season 1985/86, R = rainy season 1988.

TABLE 3
Amino acid composition (g per 100 g protein) of groundnut cultivars,[a] post-rainy season 1985/86, ICRISAT Center

Amino acid	*Whole seed*			*Blanched seed*		
	Range	*Mean*	*SE±*	*Range*	*Mean*	*SE±*
Aspartic acid	12·35–12·70	12·51	0·063	12·28–12·60	12·39	0·054
Threonine	3·09–3·32	3·18	0·045	2·74–2·91	2·83	0·035
Serine	5·21–5·49	5·38	0·049	5·13–5·49	5·32	0·060
Glutamic acid	21·55–22·01	21·75	0·099	22·02–23·39	22·66	0·265
Proline	4·57–5·47	5·05	0·153	4·62–5·07	4·82	0·090
Glycine	6·10–6·37	6·24	0·059	5·70–6·23	5·99	0·091
Alanine	4·12–4·42	4·26	0·064	4·25–4·42	4·32	0·032
Cystine	1·16–1·57	1·33	0·066	1·21–1·35	1·30	0·026
Valine	4·51–4·80	4·66	0·046	4·53–4·69	4·63	0·030
Methionine	1·22–1·38	1·30	0·033	1·21–1·39	1·33	0·034
Isoleucine	3·64–3·86	3·73	0·039	3·75–3·93	3·87	0·031
Leucine	6·84–7·27	7·09	0·087	6·87–7·17	7·02	0·056
Tyrosine	4·32–4·65	4·51	0·054	4·44–4·80	4·58	0·063
Phenylalanine	5·45–5·84	5·66	0·073	5·41–5·74	5·60	0·054
Histidine	2·74–3·11	2·92	0·062	2·72–2·92	2·81	0·040
Lysine	3·98–4·09	4·05	0·019	3·59–3·92	3·78	0·055
Arginine	12·89–13·81	13·19	0·187	12·08–13·15	12·67	0·197
Protein (%)[b]	49·00–49·70	49·3	0·153	51·40–52·30	52·00	0·178

[a] ICGS 1, 5, 11, 21 and 44. Means of two determinations.
[b] Analyses of defatted samples (N × 5·46, dry weight basis).

rainy season showed that, among all the cultivars, ICGS 21 had the highest 100-seed mass (69·3 g) and oil content (52·7%). The cultivar J 11 had significantly higher starch (14·2%), sugars (5·4%) and ash (2·5%), while Kadiri 3 exhibited significantly higher protein content (30·8%) and lower oil content (49·0%). The two controls exhibited the lowest seed mass. The results of the 1988 rainy season presented in Table 1 reveal that ICGS 21 had significantly higher oil content and 100-seed mass among all the cultivars. A comparison of the results from the two seasons' data showed that the 100-seed mass and protein contents were significantly higher in the post-rainy 1985/86 season while starch and sugars were significantly lower than the 1988 season. As oil values did not show much variation in the two seasons, the higher protein in the 1985/86 season could perhaps be associated with the lower starch and sugar levels. Dwivedi *et al* (1990) also reported a higher 100-seed mass and protein content in the post-rainy seasons. Data shown in Table 1 compare well with the reported values (Haytowitz and Matthews 1989).

Minerals and trace elements

The mineral and trace element compositions of all seven groundnut cultivars grown during the 1985/86 post-rainy and 1988 rainy season are shown in Table 2. Recommended dietary allowance suggested by the National Academy of Sciences are given for comparison (Recommended Dietary Allowances 1980). Derise *et al* (1974) reported similar values for phosphorus, potassium and calcium. However, they reported lower values for magnesium and iron and higher values for zinc, copper and manganese.

In the post-rainy season 1985/86, potassium content ranged from 631 to 700 mg per 100 g of sample. A similar magnitude of variation was also observed for phosphorus and magnesium in the post-rainy season 1985/86 (Table 2). ICGS 1 showed the highest contents of potassium, calcium and magnesium among all the cultivars in the post-rainy season. ICGS 5 was comparatively high in iron in both seasons. The concentrations of minerals in the 1988 rainy season were in general lower than in the 1985/86 post-rainy season. Among the trace elements, only iron was lower in the 1988 rainy season.

Amino acid composition

The results of amino acid analysis of whole and blanched groundnut seeds grown during the 1985/86 post-rainy season are shown in Table 3. Data obtained on these samples from the 1988 rainy season are shown in Table 4. The mean protein content of the blanched samples was higher than that of the whole seeds in both seasons. The whole seeds in both seasons had higher amounts of threonine and lysine and lower amounts of glutamic acid than the blanched samples. Large differences were

TABLE 4
Amino acid composition (g per 100 g protein) of groundnut cultivars, rainy season 1988

Amino acid	*Whole seed*					*Blanched seed*				
	ICGS cultivars[a]		*Controls*			*ICGS cultivars*[a]		*Controls*		
	Range	*Mean*	*Kadiri 3*	*J 11*	*SE±*	*Range*	*Mean*	*Kadiri 3*	*J 11*	*SE±*
Aspartic acid	11·26–11·67	11·46	11·18	11·21	0·076	11·05–11·26	11·17	11·38	11·08	0·042
Threonine	2·33–2·74	2·52	2·40	2·25	0·060	2·05–2·24	2·15	2·21	2·15	0·027
Serine	5·21–5·40	5·32	5·09	5·04	0·053	4·52–4·89	4·72	4·65	4·81	0·045
Glutamic acid	21·50–22·24	21·83	21·29	21·88	0·121	21·89–22·40	22·06	21·88	22·19	0·072
Proline	5·56–6·37	5·85	6·40	6·30	0·137	5·47–5·90	5·65	5·65	5·97	0·076
Glycine	5·47–6·13	5·86	5·51	6·42	0·142	5·97–6·22	6·07	5·65	5·87	0·069
Alanine	3·72–4·41	4·11	4·27	4·12	0·085	4·18–4·37	4·28	4·52	4·21	0·044
Cystine	1·21–1·26	1·23	1·26	1·24	0·008	1·24–1·31	1·28	1·30	1·28	0·009
Valine	4·17–4·41	4·32	4·03	4·13	0·055	4·14–4·47	4·30	4·21	4·41	0·045
Methionine	1·27–1·31	1·29	1·26	1·21	0·013	1·17–1·34	1·24	1·25	1·31	0·023
Isoleucine	3·28–3·60	3·45	3·28	3·33	0·051	3·27–3·83	3·55	3·09	3·42	0·089
Leucine	5·98–6·46	6·32	6·30	6·48	0·065	6·44–6·75	6·58	6·39	6·59	0·050
Tyrosine	3·16–3·37	3·28	3·38	3·50	0·043	4·30–4·49	4·36	4·32	4·71	0·056
Phenylalanine	4·89–5·43	5·24	4·96	5·35	0·079	5·14–5·28	5·22	5·16	5·20	0·020
Histidine	2·08–2·33	2·22	2·21	2·12	0·034	2·11–2·29	2·20	2·05	2·01	0·039
Lysine	4·12–4·56	4·30	4·40	4·47	0·068	3·92–4·27	4·05	4·26	4·31	0·061
Arginine	11·07–11·41	11·31	11·28	11·47	0·048	11·15–11·52	11·31	11·05	11·31	0·059
Protein (%)[b]	37·60–42·70	40·80	37·70	37·40	0·914	38·90–43·65	41·58	42·65	40·35	0·591

[a] ICGS 1, 5, 11, 21 and 44. Means of two determinations.
[b] Analysis of defatted samples (N × 5·46, dry weight basis).

TABLE 5
Biological evaluation of blanched seeds of groundnut cultivars grown in rainy and post-rainy seasons, ICRISAT Center

							Controls			
	Season[1]	*ICGS 1*	*ICGS 5*	*ICGS 11*	*ICGS 21*	*ICGS 44*	*Kadiri 3*	*J 11*	*Casein*	*SE±*
Biological value (%)	PR	53·5^{b}	52·7^{b}	51·5^{b,c}	56·6^{b}	47·7^{c}	NA	NA	76·0^{a}	4·11
	R	64·2^{a}	60·9^{a}	61·6^{a}	60·9^{a}	61·5^{a}	61·0^{a}	63·6^{a}	NA	0·52
True digestibility (%)	PR	96·3^{b,c}	95·4^{c}	98·2^{a,b}	99·2^{a}	96·4^{b,c}	NA	NA	96·4^{b,c}	0·58
	R	93·9^{a}	93·2^{a}	93·4^{a}	91·8^{a}	92·4^{a}	93·0^{a}	93·4^{a}	NA	0·27
Net protein utilisation (%)	PR	51·5^{b,c}	50·3^{b,c}	50·7^{b,c}	56·1^{a}	46·0^{c}	NA	NA	73·3^{a}	3·96
	R	60·3^{a}	55·5^{a}	57·5^{a}	56·0^{a}	56·7^{a}	56·7^{a}	59·4^{a}	NA	0·67
Utilisable protein (%)	PR	25·1^{b,c}	25·4^{b,c}	24·7^{c}	28·4^{a}	22·8^{c}	NA	NA	64·3^{a}	6·55
	R	25·6^{a}	23·7^{a,b}	24·7^{a}	22·2^{a}	24·0^{a}	24·6^{a}	23·9^{a,b}	NA	0·40
Protein efficiency ratio	PR	2·41^{b}	2·42^{b}	2·35^{b}	2·33^{b}	2·28^{b}	NA	NA	3·21^{a}	0·144
Protein (%)	PR	48·7	50·5	48·8	50·0	49·5	NA	NA	87·8	6·40
	R	42·5	42·7	43·0	39·8	42·3	43·4	40·2	NA	0·53

[1] PR = Post-rainy season 1985/86, R = rainy season 1988. NA = Not analysed.
Values with the same superscript in each row do not differ significantly from each other.

observed between whole seed and blanched samples for the means of serine (5·32 and 4·72 g per 100 g protein) and tyrosine (3·28 and 4·36 g per 100 g protein) in the rainy season 1988. The protein content of cultivars in the post-rainy season 1985/86 was higher than in the rainy season 1988. In spite of this, the 1985/86 post-rainy season cultivars had higher concentrations of many amino acids (eg threonine, cystine, methionine, valine and isoleucine) than the cultivars of the rainy season 1988, showing their improved protein content and

TABLE 6
Biological evaluation of blanched and whole seeds of groundnut cultivars, rainy season 1988, ICRISAT Center

	ICGS 21		*J 11*		*Kadiri 3*		*SE±*	
	Blanched seed	*Whole seed*	*Blanched seed*	*Whole seed*	*Blanched seed*	*Whole seed*	*Blanched seed*	*Whole seed*
Biological value (%)	60·9	58·4	63·6	67·1	61·0	66·2	0·88	2·76
True digestibility (%)	91·8	87·6	93·4	90·6	93·0	89·0	0·48	0·87
Net protein utilisation (%)	56·0	51·1	59·4	60·8	56·7	59·0	1·04	2·98
Utilisable protein (%)	22·2	18·8	23·9	23·7	24·6	22·3	0·71	1·46

quality. The amino acid composition reported here is similar to and within the range of that reported by Young *et al* (1973).

Biological evaluation of protein quality

The rat bioassay of groundnut cultivars grown during the 1985/86 post-rainy season and 1988 rainy season was carried out on blanched samples along with casein as a control (Table 5). In the post-rainy season 1985/86, ICGS 21 showed the highest values of BV, TD, NPU and UP among all the groundnut cultivars. The lowest values of BV, NPU and UP were found with ICGS 44. The values for BV, NPU and UP of three cultivars ICGS 1, ICGS 5 and ICGS 11 did not differ significantly. There were no significant differences in the PER among the groundnut cultivars, which ranged from 2·28 to 2·42. The protein content in the defatted samples in the five ICGS cultivars varied from 48·7 to 50·5%. Data obtained from these experiments demonstrate that groundnut protein has an excellent digestibility (above 95%) and an NPU of around 50%. The utilisable protein among the five ICRISAT groundnut cultivars ranged from 22·8 to 28·4% as compared with the high value of 64·3% for casein. In contrast to the results of the 1985/86 post-rainy season, where ICGS 21 showed high NPU, BV and TD, there were no significant differences in NPU, BV and TD percentages among the cultivars in the 1988 rainy season. ICGS 1 had the highest percentages of BV, NPU, TD and UP among the seven groundnut cultivars (Table 5). Miller *et al* (1978) reported that PER of several groundnut cultivars ranged from 2·30 to 2·54 when fed at 12% protein level in the diet, and their digestibilities ranged from 91·0% to 92·4%. These values are similar to the values reported here. True digestibility was significantly higher in the 1985/86 post-rainy season whereas BV and NPU were significantly higher in the 1988 rainy season. However, no significant differences were observed in UP between the two seasons. Total quantity of amino acids consumed based on actual diet intake revealed that, in the case of 1988 rainy season cultivars, rats consumed a higher amount of lysine and sulphur amino acids, which could explain the associated higher BV observed.

Influence of seed coat on protein quality

To study the effect of seed coat on the digestibility and net protein utilisation of groundnut, rat bioassay was carried out simultaneously on the blanched and whole seed samples using three cultivars obtained from the 1988 rainy season (Table 6). True digestibility was significantly lower in whole seed samples (mean 89·1%) than in blanched samples (mean 92·7%). The lower digestibility in the case of the whole seed sample could be due to the presence of certain protein inhibitors, polyphenols and tannins in the seed coat (Elias *et al* 1979). Interestingly, the biological value of the whole seed samples was higher (though not significantly) than the blanched samples in two cultivars. This could be a result of the improved amino acid (lysine and threonine) composition in the whole seed due to the contribution of seed coat when compared with the blanched seed. Net protein utilisation was not significantly different between blanched and whole seeds. Utilisation of protein was significantly higher in the blanched seed (mean 23·6%) than in whole seed (mean 21·6%) (Table 6).

CONCLUSIONS

Results from this investigation have made it possible to compare the two seasons' data obtained on nutritional quality of ICRISAT groundnut cultivars with those of control cultivars that have been cultivated in India for several years. ICRISAT cultivars showed consistently higher oil content in both the seasons than those of the controls. Groundnut cultivars in the post-rainy season showed significantly higher values for protein content, 100-seed mass, potassium, calcium, iron and true digestibility of protein than in the rainy season. However, starch, sugars, zinc, manganese, biological value and net protein utilisation were higher in the rainy season than in the post-rainy season. The differences in various quality parameters between rainy and post-rainy seasons may be

due to genotype and season effects. The higher seed mass in the post-rainy season may be due to better growing conditions and management because foliar diseases are minimal or absent in the post-rainy season.

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