Food Chemistry **24** (1987) 29–35

Maturation Stage and Mineral Content in Soybeans

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(Received 25 March 1986; revised version received 2 May 1986; accepted 29 August 1986)

ABSTRACT

The mineral content of three soybean varieties (Hill, Wright and Centennial) at different maturation stages was determined by neutron activation analysis for immature, green mature and dry mature stages. The mean concentrations of the elements at the three stages were as follows: Al (μg/g) 14·7, 16·0 and 16·7; Br (μg/g) 2·53, 1·60 and 1·59; Ca (mg/g) 3·44, 2·98 and 2·73; Cl (μg/g) 105, 88·3 and 75·6; Fe (μg/g) 72·2, 73·9 and 61·2; K (mg/g) 17·8, 21·3 and 19·9; Mg (mg/g) 2·55, 2·62 and 2·63; Mn (μg/g) 28·6, 29·7 and 28·3; Na (μg/g) 102, 84·5 and 51·4; Rb (μg/g) 6·80, 9·02 and 6·55; and Zn (μg/g) 55·6, 56·5 and 53·4. Among the elements determined, only Rb and Br concentrations varied significantly between immature and green mature soybeans; Rb concentration varied between green mature and dry mature soybeans and Na concentration varied between immature and dry mature soybeans.

INTRODUCTION

During maturation of soybeans, and due to biochemical changes, (a) the composition of lipids completely changes; the content of crude protein increases and the concentration of vitamin C and β carotene decreases (Liener, 1972; Rackis, 1981), (b) the trypsin inhibitor activity increases (Sarett, 1976) and (c) the lipoxygenase activity increases (Rackis, 1978; Yoa *et al.*, 1983). The effect of maturation on water, protein, fat and amino acids has been reported by Krivoruchco *et al.* (1979). The changes in biochemical and food values during the maturation of soybeans have been

Food Chemistry 0308-8146/87/$03·50

reviewed by Rackis (1978, 1981). Liener (1972) indicated that the contents of Ca, P and Fe were increased by maturation. However, data available relating the mineral content to maturation stage are limited and show a wide range of values (Rackis, 1981). The elemental concentration in soy protein was published by Osborn (1977), where 87 elements were determined in defatted soybeans by single-element or multi-element techniques. The performance of neutron activation analysis, a multi-element analytical method, compared favorably with single-element techniques.

The objective of this study was to determine the Al, Br, Ca, Cl, Fe, K, Mg, Mn, Na, Rb and Zn in soybeans in three soybean varieties at different maturation stages.

MATERIALS AND METHODS

Materials

Soybean plants of Hill, Centennial and Wright varieties were grown for this study on the Experimental Farm of the Suez Canal University at Ismailia, Egypt. The soybeans were harvested at three different maturation stages (Table 1). The samples were dried at 105°–108°C until a constant weight was obtained, then ground and stored in sealed containers for analysis.

Methods

The mineral content of soybeans was determined by non-destructive neutron activation analysis. An approximately 0·3–0·4 g sample was thermally sealed in a high purity polyethylene container. The standard used included National Bureau of Standards Standard Reference Materials Orchard leaves; citrus leaves, in addition to high purity (>99·99%) salts, were also used. Data pertaining to the determination of the elements of

TABLE 1
Phenotypic Characteristics of Soybean Varieties

Soybean variety	*Days from planting until*			
	Flowering	*Immature*	*Green mature*	*Dry mature*
Hill	50	97	112	123
Centennial	60	106	121	138
Wright	62	109	123	140

TABLE 2
Nuclear Reaction and Data for the Determination of Eleven Elements in Soybeans

Element	*Nuclear reaction and products*	*Half life*	*γ-ray (keV)*	*Time of irradiation*	*Time of decay*	*Time of counting*
Al	$^{27}Al(n, \gamma)^{28}Al$	2·24 min	1779	5 min	1 min	5 min
Br	$^{81}Br(n, \gamma)^{82}Br$	35·34 h	776	8 h	1 day	1 h
Ca	$^{48}Ca(n, \gamma)^{49}Ca$	8·72 min	3084	5 min	1 min	5 min
Cl	$^{37}Cl(n, \gamma)^{38}Cl$	37·29 min	1642	5 min	30 min	15 min
Fe	$^{58}Fe(n, \gamma)^{59}Fe$	44·56 days	1099	8 h	20 days	10 h
K	$^{41}K(n, \gamma)^{42}K$	12·36 h	1525	8 h	1 day	1 h
Mg	$^{26}Mg(n, \gamma)^{27}Mg$	9·46 min	1014	5 min	1 min	5 min
Mn	$^{55}Mn(n, \gamma)^{56}Mn$	2·58 h	847	5 min	30 min	15 min
Na	$^{23}Na(n, \gamma)^{24}Na$	15·03 h	1368	8 h	1 day	1 h
Rb	$^{85}Rb(n, \gamma)^{86}Rb$	18·82 days	1077	8 h	20 days	10 h
Zn	$^{64}Zn(n, \gamma)^{65}Zn$	244·02 days	1116	8 h	20 days	10 h

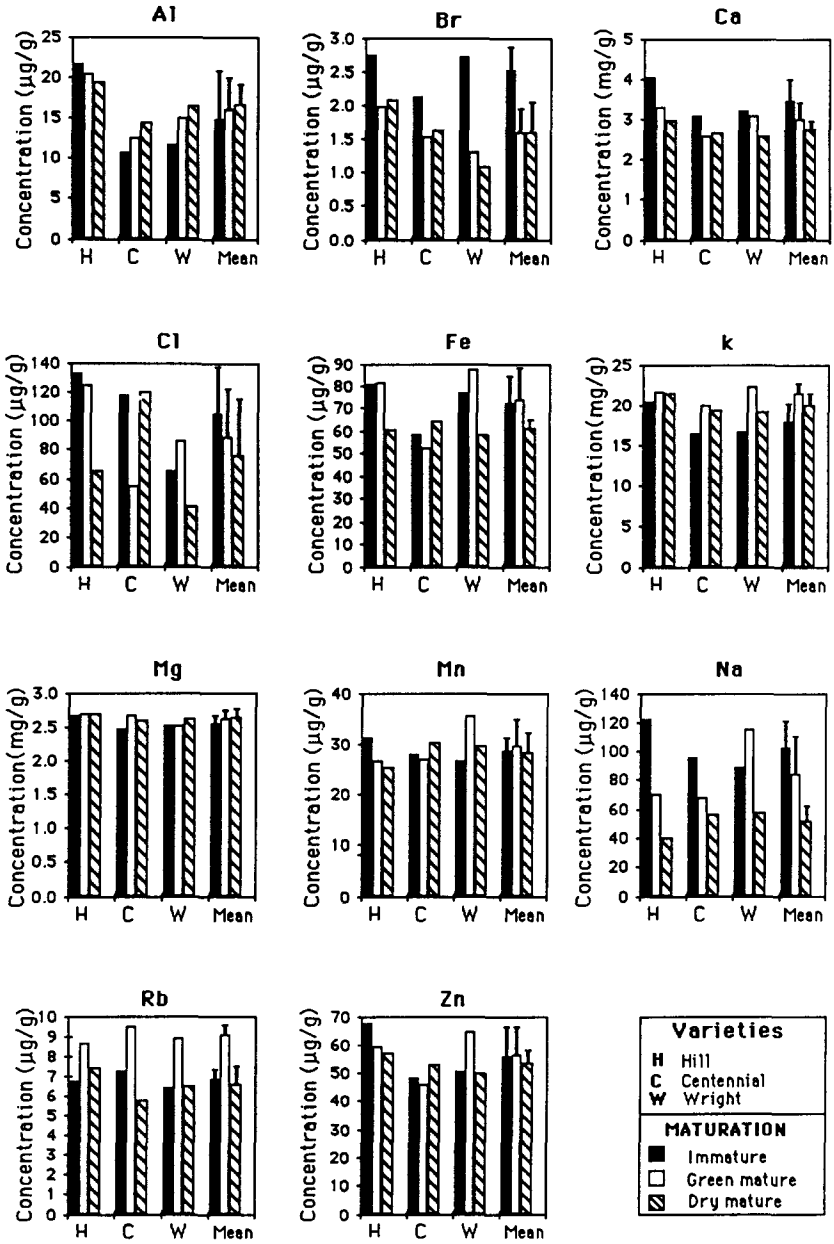

Fig. 1. Concentration of eleven elements at immature, green mature and dry mature stages for three soybean varieties.

TABLE 3
Concentration of Eleven Elements in Three Soybean Varieties at Three Maturation Stages[a]

Element	*Immature*		*Green mature*		*Dry mature*	
	Range	*Mean ± SD*	*Range*	*Mean ± SD*	*Range*	*Mean ± SD*
Al	10·7 – 21·6	14·7 ± 6·0	12·6 – 20·4	16·0 ± 4·0	14·4 – 19·4	16·7 ± 2·5
Br	2·13 – 2·73	2·53 ± 0·34	1·30 – 1·98	1·60 ± 0·35	1·09 – 2·06	1·59 ± 0·49
Ca	3·10 – 4·02	3·44 ± 0·51	2·60 – 3·08	2·98 ± 0·34	2·58 – 2·95	2·73 ± 0·19
Cl	65·1 – 132	105 ± 35	55·3 – 124	88·4 ± 34	41·1 – 120	75·6 ± 40
Fe	58·6 – 87·1	72·2 ± 12	52·5 – 87·6	73·9 ± 19	58·3 – 64·2	61·2 ± 3·0
K	16·4 – 20·4	17·8 ± 2·3	20·0 – 22·2	21·3 ± 1·1	19·1 – 21·3	19·9 ± 1·2
Mg	2·46 – 2·66	2·55 ± 0·10	2·52 – 2·69	2·62 ± 0·09	2·61 – 2·69	2·63 ± 0·09
Mn	26·6 – 31·1	28·6 ± 2·3	26·5 – 35·6	29·7 ± 5·1	25·2 – 30·3	28·3 ± 2·7
Na	88·0 – 122	102 ± 18	68·3 – 115	84·5 ± 26	40·5 – 57·7	51·4 ± 9·5
Rb	6·45 – 7·23	6·80 ± 0·40	8·68 – 9·50	9·02 ± 0·43	5·73 – 7·42	6·55 ± 0·85
Zn	48·5 – 67·5	55·6 ± 10	45·9 – 64·5	56·5 ± 9·6	49·8 – 57·2	53·4 ± 3·7

[a] Concentration in μg/g, except for CA, K and Mg (in mg/g).

interest and the experimental parameters are shown in Table 2. The emitted gamma-rays from the indicator radionuclides were counted with a high purity germanium coaxial detector (EG&G ORTEC). Data acquisition and data reporting were controlled by a local computer (EG&G ORTEC).

RESULTS AND DISCUSSION

The composition of soybean seed is varied and affected by genetic factors, agricultural methods, soil composition, environmental conditions (such as fertilizer used) and climate. For the three varieties used in this study, all of these factors, with the exception of genetic were kept the same. Thus, the influence of irrigation water, fertilizer and soil composition on the element content of the examined soybean seeds was nullified.

Figure 1 shows the concentration of Al, Br, Ca, Cl, Fe, K, Mg, Mn, Na, Rb and Zn in immature, green and dry mature soybeans of three varieties. The concentration of the elements at each maturation stage was averaged over the varieties examined and is shown in Table 3. The concentrations of Al, Mn, Mg, Ca and K in dry mature soybeans are similar to those reported by Markley & Goss (1944). Also, the concentrations of K, Ca and Mg given by O'Dell (1979) fall mainly within the range of the figures of our study. The concentration of Fe in immature and mature soybeans is slightly higher than that reported by Welch & Van Campen (1975).

Statistical testing of the mean concentration of the eleven elements, by applying the t-distribution test at 5% significance for a two-tailed test, shows that there are no significant differences between the element concentration in immature and green mature soybeans except for Rb and Br, where the mean concentration of the element varied significantly. The test also shows that there are no significant differences between the mean concentrations of Al, Br, Ca, Fe, K, Mg, Mn, Na and Zn in green mature and dry mature soybeans.

The correlation between the elemental content at the different maturation stages was studied to see if such correlation depends on maturation. No consistent trend was noticed. For example, during the immature stage, Na showed high positive correlation ($r = > 0{\cdot}950$) with Ca and Zn. Upon maturation this correlation became highly negative ($r = < -0{\cdot}950$).

ACKNOWLEDGEMENT

The author wishes to thank Professor A. Askar for providing the samples for the study.

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