Winged Bean Protein
—in Comparison with Other Legume Protein—

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More than ten thousand of legume plants are known to exist on the earth, whereas about one hundred spieces of them are directly edible, and many other legumes are utilized as forages or manures for food crops. Since National Academy of Science, U.S.A. reviewed hopeful plants in the world in 1974,[9] winged bean (*Psophocarpus tetragonolobus*) has been given a special attention among these legumes, with the following points of view:

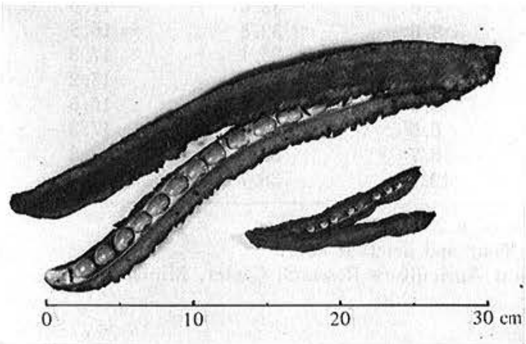


Plate 1. Fresh winged bean. The smaller one (15–25 days after flowering) is suitable for eating with pods. The larger one (more than 30 days after flowering) is almost matured.

1. All parts of winged bean plant are edible and protein-rich.[2] It is remarkable that not only the seeds but also leaves and tubers contain protein of more than 20% per dry material.
2. Protein and fat contents of seeds are very high among legumes (Table 1–1).[4] Winged bean contains 30 to 40% protein. Though sulfer-containing amino acids are of small amounts, lysine (an essential amino acid) content is fairly high, which is quite similar to soybean (Table 2).[6] The fat content reaches up to 20%, and about 70% of it is unsaturated fatty acids.[1]
3. Cultivation of winged bean is not difficult. It is found to nodulate more easily and heavily than any other legumes. With this advantageous characteristic, it is suggested that winged bean is a promising rotational crop to maintain or enhance soil fertility for following crops. No serious pests and diseases have been found in a small scale cultivation so far, although those in large scale cultivation might spread without treatments of prevention.
4. The potential of seed production seems not to be low. The yield of 2,612 kg/ha, for example, is marked with an experimental cultivation in Indonesia,[16] though the yields of less than 1,000 kg/ha were noted with some traditional cultivations.
5. Inhibitors in the seeds to physiological activities of animals, which are known to exist in many legume seeds, are able to be inactivated by heat treatment, and the content is not more than that in other edible legumes.
6. Winged bean originated from a tropical or subtropical area, where soybean or other main legumes are not suitable to grow, and requirement for protein-rich foods is serious.
7. Since systematic application of breeding techniques and research of cultivation have not been enough yet, there seems to be a reasonable possibility of improving or selecting more useful varieties of winged bean (The future of winged bean seems firstly to depend on this point).

Protein and amino acid contents in winged bean seeds

Components of main edible legume seeds are

Table 1-1. Components of main edible legume seeds

		Water	Protein	Fat	Carbohydrate
Lupin	*Lupinus*	8	44.3	16.5	35.3
Soybean	*Glycine max*	8	38.0	18.0	36.1
Winged bean	*Psophocarpus tetragonolobus*	9	36.6	15.3	35.6
Fenugreek	*Trogonella foenum-graecum*	9	29.0	5.2	64.4
Groundnut	*Arachis hypogaea*	5	25.6	43.4	26.7
Adzuki beans	*Phaseolus angularis*	13	25.3	0.6	62.8
Lentil	*Lens esculenta*	11	24.2	1.8	63.9
Tepary bean	*Phaseolus acutifolius*	10	24.0	1.0	66.0
Mung beans	*Phaseolus mungo, aureus*	11	23.9	1.3	64.6
Broad bean	*Vicia faba*	11	23.4	2.0	68.0
Cowpea	*Vigna unguiculata*	11	23.4	1.8	64.6
Peas	*Pisum sativum*	11	22.5	1.8	67.6
Common beans	*Phaseolus vulgaris*	11	22.1	1.7	65.6
Pigeon pea	*Cajanus cajan*	11	20.9	1.7	70.9
Chick peas	*Cicer arietinum*	11	20.1	4.5	66.4

(Made from the data of Reference 4)

Table 1-2. Composition of winged bean seeds[18]

Line		Moisture	Protein[a]	Fat[b]
O-001[c]	Indonesia	7.6	32.6	17.6
O-002	Indonesia No. 902	8.6	32.8	16.5
O-003	Indonesia No. 909	8.3	35.1	17.3
O-004	Indonesia No. 1126 (1)	7.2	37.2	15.2
O-007	Nigeria Tpt 2	6.9	34.8	16.6
O-012	Papua New Guinea UPS 122	6.5	33.7	17.3
O-013	Ishigaki	6.7	32.3	15.8
F-UPS 99[d]	Papua New Guinea	12.2	38.7	15.9

a): Percentage to dry weight, calculated by multiplication of 6.25 to total nitrogen.
b): Estimation from the weight difference between whole flour and defatted flour.
c): Numbered and cultivated at Okinawa-branch of Tropical Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries.
d): Cultivated at Kyushu University, Fukuoka.

shown in Table 1-1.[4] Winged bean seeds contain 30 to 40% protein, which is equal to some lupins and soybeans. These three beans are not only the most protein-rich edible legumes but also fat-rich, except the distinguished fat content of groundnut. Though seed components in different varieties are known to diverse considerably even among the same species, the protein contents of winged bean seeds are very high in any analyzed lines[7] (Table 1-2).[18] Amino acid composition in winged bean seeds are almost similar to those of soybean (Table 2).[6] As mentioned before, content of lysine (an essential amino acid) is higher than other main legume seeds, and percentages of glutamine (+glutamic acid) and asparagine (+asparagic acid) are high, as the general property of legume seeds.

Extraction of seed proteins

Derbyshire et al.[3] reviewed legume storage proteins with 271 references, and grouped the legume storage proteins into two, legumin-like (sedimentation coefficients of 10 to 13S) and vicilin-like (6 to 9S). Extractabilities of legume seed protein are much larger than those of cereals. However, as the studies on various legume protein have been proceeded in arbitrary conditions with wide range of extractabilities, the data should be compared very carefully.

Studies on winged bean seed protein components extracted with acidic buffer[6] or water[12] have been reported. We extracted more than 90% protein of winged bean seeds at about

Table 2. Amino acid compositions of defatted seed meals from winged bean (*Psophocarpus tetragonolobus*), soybean (*Glycine max*), and Lupin (*L. angustifolius* cv. Uniharvest)[4]

Amino acid	Composition (residues/100 residues)			Amino acid	Composition (residues/100 residues)		
	Winged bean	Soybean	Lupin		Winged bean	Soybean	Lupin
Lys	6.8	5.7	4.5	Ala	6.1	6.6	5.1
His	2.4	2.2	2.3	1/2Cys*	1.7	1.8	1.8
Arg	5.3	6.0	8.7	Val	4.5	4.2	4.5
Asp	11.1	12.0	11.1	Met	0.9	1.3	0.3
Thr	4.7	4.8	3.8	Ile	3.9	3.5	4.4
Ser	7.3	7.4	6.5	Leu	8.8	7.5	7.3
Glu	13.5	16.4	20.9	Tyr	4.2	2.9	3.1
Pro	7.6	6.0	4.7	Phe	4.1	4.0	3.4
Gly	7.3	7.8	8.0				

* Estimated as cysteic acid.

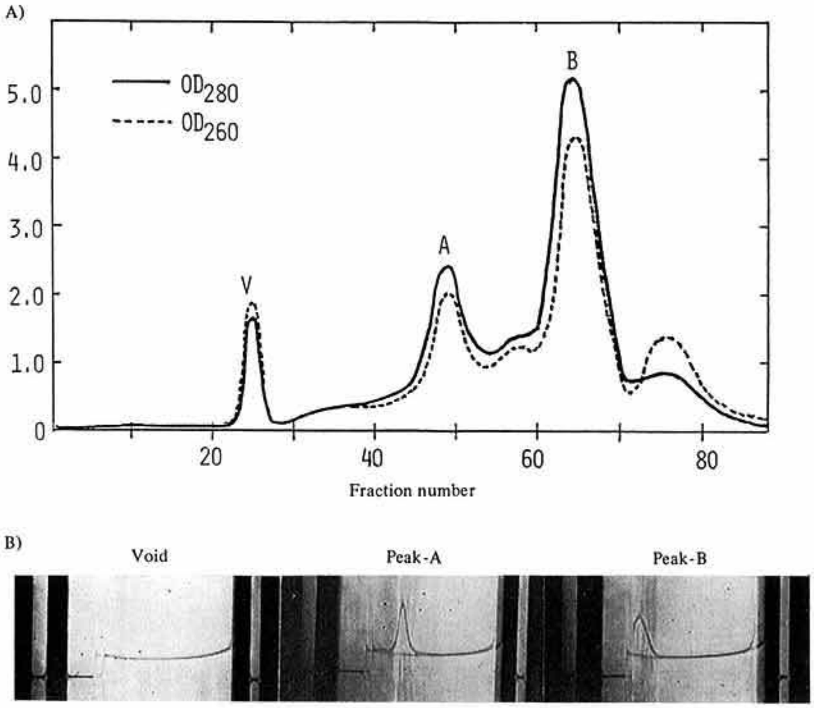


Plate 2. A) Fractionation of whole winged bean seed protein through Sepharose 6B column chromatography
B) Sedimentation patterns of fractionated winged bean protein through Sepharose 6B chromatography

neutral pHs and ionic strengths of 0.3 to 0.5,[19] which was comparable to many studies on soybean and other seed proteins.

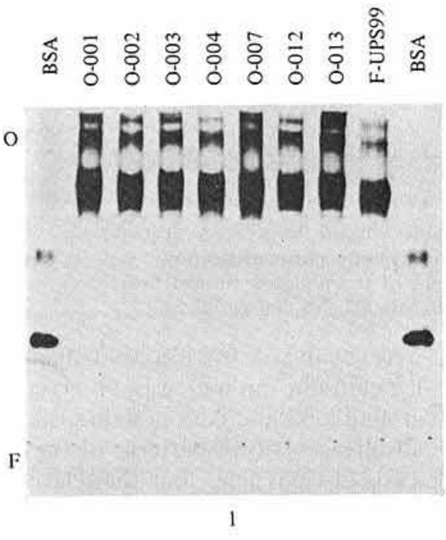
Identification of winged bean storage protein

Seed proteins from eight lines of winged bean were analyzed by ultracentrifugation, and no legumin-like protein was observed.[18] Both of around 2.5S and 6.5S protein peaks were seen in all ultracentrifuge patterns of the extracts from seeds of eight lines. but the relative amounts of the peaks fluctuated considerably with the lines. The components of 2.5S and 6.5S could be separated with Sepharose 6B column chromatography (Plate 2).[19] The 2.5S components were the combinations of several different proteins, but the major components of 6.5S proteins showed the same movilities in polyacrylamide gel electrophoresis (Plate 3).[18] The 6.5S components, therefore, are mainly the common storage protein of winged bean seeds. This component(s) varied in the sedimentation coefficient (S_{20}, $\mu=0.5$) from 6.0 to 6.6 with the difference of lines.[18] Since the eight lines examined were originally introduced from several countries and grown in Okinawa and Fukuoka, Japan, the phenomena mentioned above seemed to be almost general in winged bean proteins.

Protein constructions of winged bean, soybean and common bean in various solutions

Sedimentation patterns of legume seed protein change with pH and ionic strength of the solutions. The typical association-dissociation phenomena of winged bean (Indonesia No. 909), soybean (Norin No. 2) and common bean (Kintokimame) are shown in Plate 4.[19] The profiles of winged bean protein are fundamentally similar at the pH 4.0 (data not shown) to pH 9.0, but the S values are larger at acidic pH and smaller at basic pH. The sedimentation coefficients of the main soybean protein are about 7S and 11S at pH 7.5, but the peaks shift to about 8.5S and 14S respectively at pH 4.5, and shift to smaller S values at pH 9.0. The profiles of common bean are quite different from these two beans. The most part of 7S protein at neutral pH is associated into about 18S protein at pH under 6.0 (This phenomena were also observed in French bean[14]). At pH 10.0, all proteins of the three beans are dissociated to 2 to 4S components. These phenomena distinctly show that winged bean 6.5S protein(s) is different from the most part of common bean 7S protein, though *Psophocarpus* and *Phaseolus* are thought to be near families in plant taxonomy.

According to the change of ionic strength, winged bean and common bean proteins do not show any appreciable change, except that the S values of peaks are smaller at high ionic strength and larger at low ionic strength. Soybean proteins, however, showed quite different sedimentation diagrams. The well known two main components, 7S and 11S are seen at ionic strength of 0.5. The separation of the two peaks was clearer at higher ionic strength, and the two peaks are very close at lower ionic strength. Though it is suggested that components of winged bean and soybean proteins are very similar, the details of protein molecules are quite different as shown here.



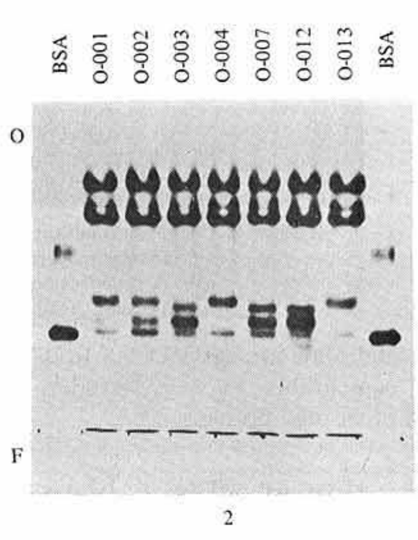
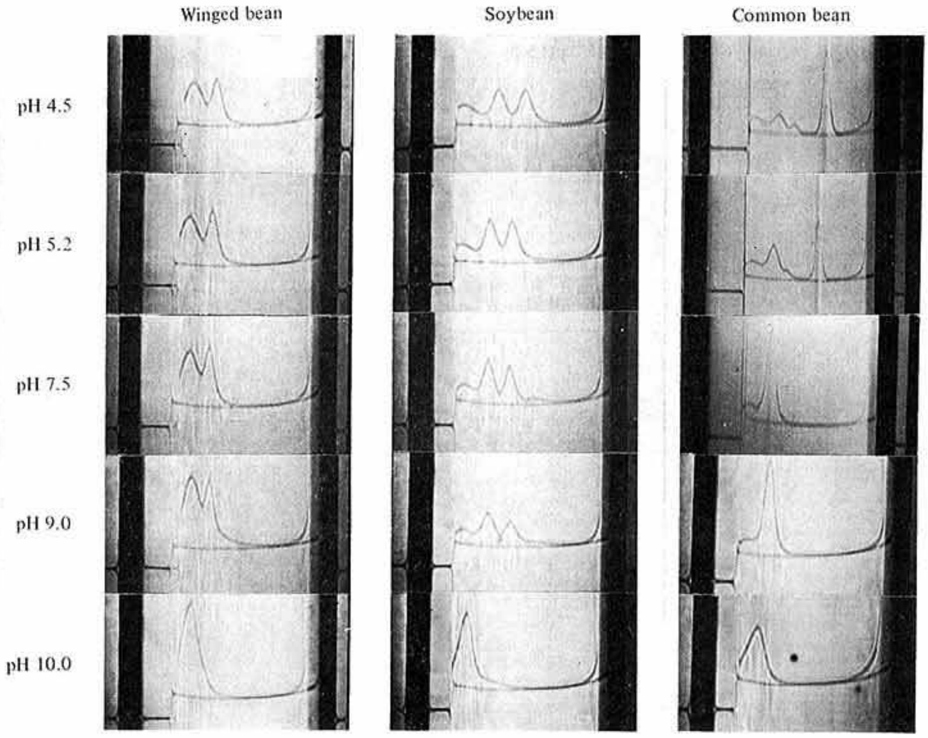
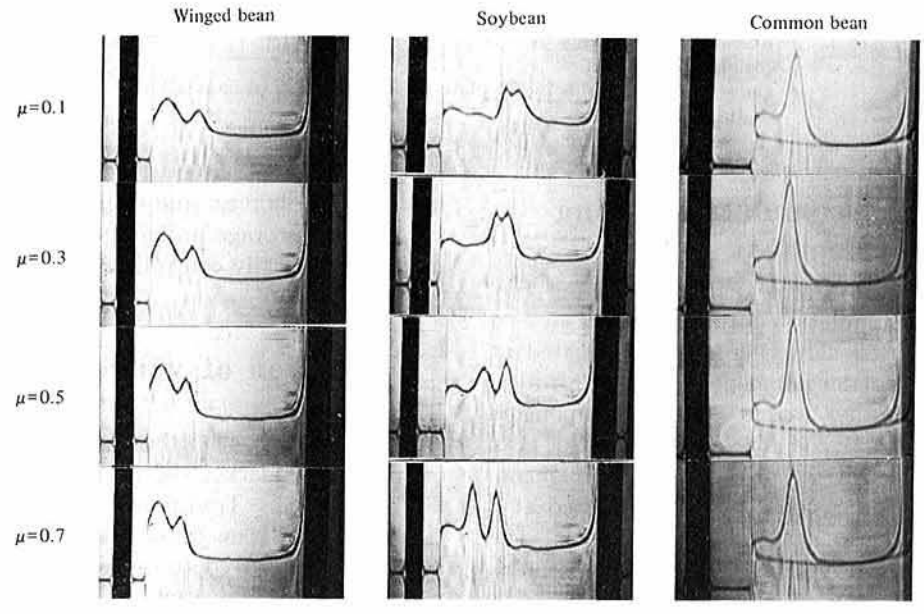


Plate 3. 1. Polyacrylamide gel electrophoresis of Sepharose 6B-peak A components (6.5S fraction)
2. The same of peak B components (2.5S fraction)



1. At various pH



2. At various ionic strength

Plate 4. Schlieren patterns of whole seed extracts from winged bean (Nigeria Tpt 2), soybean (Norin No. 2) and common bean (Kintoki-mame)

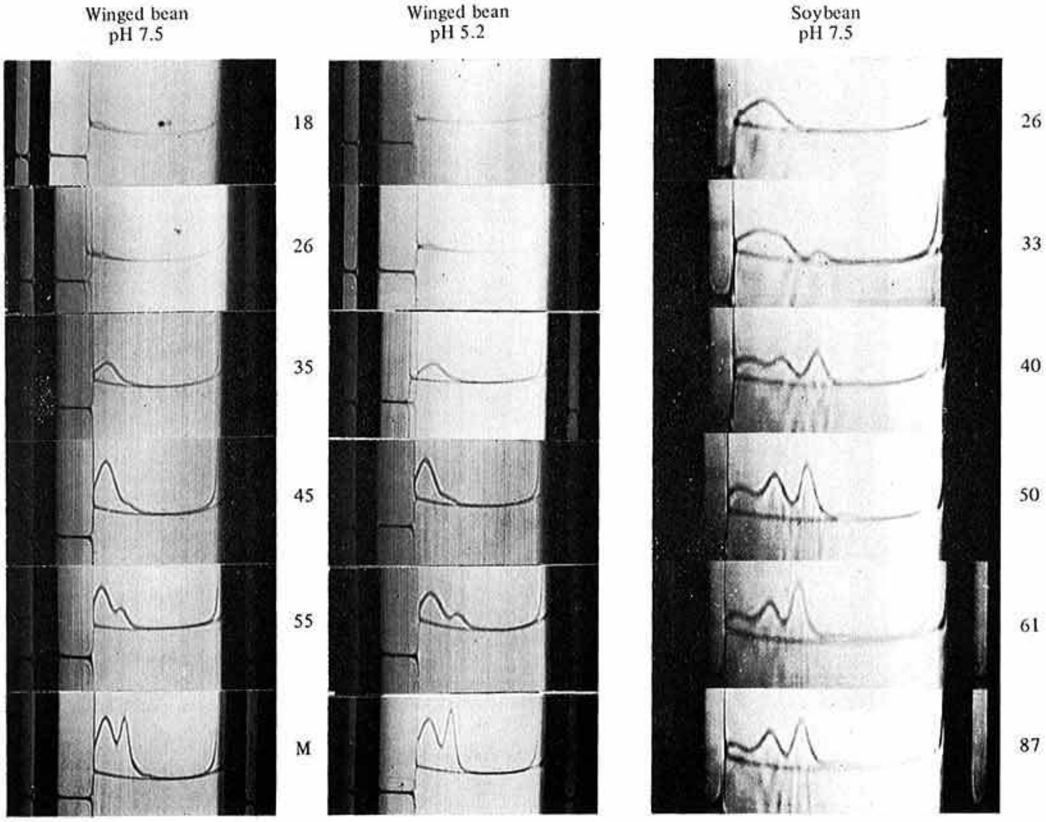


Plate 5. Sedimentation diagrams of diveloping winged bean (UPS 99) and soybean (Oguradaizu) extracts
The series of numerals in the plate indicate number of days after flowering.
M: time of maturity.

Protein accumulation during seed development

Protein accumulation during winged bean seed maturation after flowering was investigated at several stages of development[20] (Plate 5). Initially small molecular weight nitrogen-components which can be dialyzed out are accumulated, next broad peak of rather small S value components appears, and 6–8S components are formed at a considerably late stage of maturation. The phenomena observed at pH 7.5 are fundamentally same as those at pH 5.2, which demonstrates no appearance of 18S component at any stage (*Phaseolus vulgaris* has 18S component at pH 5.2). The time course of seed protein synthesis during soybean maturation (Plate 5[17]) was principally similar to that in winged bean and French bean (electrophoretic study[15]). These facts may suggest that storage protein genes of the legume might be generally controlled by similar biological mechanisms.

Utilization of winged bean

Winged bean has long been eaten as a domestic or small scale market vegetable in large areas of Southeast Asia. Traditional methods of utilization of winged bean developed in those districts have to be improved, and spread to other areas where winged bean will be introduced. As mentioned above, chemical structure of winged bean protein is quite different from soybean, and the structure of tissues are observed to be different, thicker cell walls for instance, from soybean.[11] Thus whether or not the various methods for utilization of other beans, especially soybean, are applicable to winged bean is a future problem. Anyhow the trials have been started.[5,8,10,13]

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