Progressive Farming,Vol.5, No.4,1985.

Soybean - the gold from the soil

*M. AKMAL KHAN**

The history of soybean is a fascinating story of a little round bean that has literally been a golden nugget to the oriental world. Soybean is perhaps the world's oldest food crop known to man and used as a source of food since 3000 B.C. It has earned a place in the worldwide scheme of food production because of its agronomic adaptability and high per hectare productivity of quality products — namely protein and edible fat. Nutritionally, soybean means meat, milk, cheese, bread and oil to the people of Asia for centuries. In food-deficient countries, the pressure on land is so much that production of animal protein cannot be enhanced much. From a hectare of land, soybean yields five times more protein and 19 times more calories than beef. The efficiency of production of various food crops and number of people to be fed are given in Tables 1 and 2.

With a view to increasing food supply, cultivation of soybean is desirable, not only from the viewpoint of yield but also from the cost consideration which is much more lower than the cost of many other foods. This paper highlights the nutritional value and utilization of soybeans.

NUTRITIONAL VALUE

The nutritional aspect of soybeans are being discussed in terms of (i) composition, (ii) availability or digestibility of nutrients and (iii) anti-nutritional factors.

Soybean is composed of the hull, cotyledon and hypocotyl in amounts of 8 percent, 90 percent and 2 percent, respectively. The major product from soy processing is soy-oil. After the oil is extracted, the defatted soybeans are made into

Soybean crop at NARC

**National Agricultural Research Centre, Islamabad*

Table 1. Relative efficiency of food production

	Million calories per hectare		
Beef	0.4	Grain	5.3
Eggs	0.5	Rice	6.6
Butter	0.8	Soybean	7.2
Milk	1.8	Potato	11.6
		Banana	12.6
		Sugar	25

Land needed to produce 20 kg protein in one year under various crops (acres)

Vegetable crop		Animal crop	
Soybean	0.07	Dairy cows	0.44—1.1
Bean	0.1	Fowls	1.4
Cereals	0.23	Sheep	0.8—1.9
Potato	0.27	Beef	1.0—2.5

Bender, A.E. (1979) Food Technology in Australia, 31, 108

defatted soy-flour, soy-protein concentrate or isolate soy-protein. The composition of these products is listed in Table 3. Soy-isolate is an important soy-protein product used in the infant formula and as a meat extender.

Table 2. Number of people who could theoretically be fed for one day by protein food from various sources based on production from 1 hectare of land in 1 year assuming 60 g protein intake/capita/day

Protein source	Number of people
Beef	190
Poultry	457
Milk	583
rice (white)	2469
Cottonseed	1793
Peanuts (groundnut)	2536
Wheat flour (white)	2712
Corn flakes	2828
Wheat flour (whole)	3391
Dry beans	4315
Potatoes	5239
Soybeans	9075

Animal protein data calculated from 'Comparative Proteins, D. Carton, American Soybean Association Meeting, 1967.

Other data are based on USDA world average yields, 1971

Protein

The protein content of whole soybeans (40 percent) is approximately one-and-a-half times that of lentil, twice that of chickpea and meat, four times that of egg, wheat and other cereals, six times that of bread and 12 times that of milk. Because of their great food value, soybeans are known as "meat without bone".

Protein Quality

Proteins are made of amino acids. Essential amino acids cannot be synthesized by humans and must be supplied by the diet. They include isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine. The pattern of amino acids is more important in determining protein quality than the absolute content of each essential amino acid. In Table 4, soy-protein is compared with an FAO standard for amino acid

Table 3. Typical chemical composition of soy-protein products (g/100g)

Product	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
Whole soybean	10.0	41.0	20.0	2.3	5.4	31.3
Soy-flours	7.0	50.0	1.0	3.5	6.0	39.5
Concentrates	4.0	70.0	1.0	4.5	5.0	19.5
Isolates	4.0	96.0	0.1	0.1	3.!	0.3

Johnson, D. W. (1975) Soybean Production, Protection and Utilization. INTSOY Series No. 6.

Table 4. Amino acid profile of reference pattern and soybean protein (g/16gN)

Amino acid	FAO/WHO child	Pattern adult	Soy-protein
Isoleucine	4.0	1.8	4.2
Leucine	7.0	2.5	7.4
Lysine	5.5	2.2	6.4
Phenylalanine	2.4	1.5	4.5
Total sulphur amino acids	3.5	2.4	2.2
Threonine	4.0	1.3	3.6
Tyrosine	—	—	3.4
Tryptophan	1.0	0.6	1.7
Valine	5.0	0.8	4.3

FAO (1968) Amino acid content of foods and biological data on proteins.

balance. The amino acids whose levels are less than the reference pattern are termed limiting. The amino acid that is most deficient is called the first limiting amino acid. In soy-protein, the sulphur containing amino acid methionine is first limiting.

Extensive feeding studies on animals and humans indicate that soy-foods are well utilized. Retention of nitrogen in infants fed on soy-isolate was similar to values for cow milk. Children fed on soy-protein isolate-based foods retain adequate amount of nitrogen and grew well. Soy-isolate has also been found to meet the essential amino acid pattern needs of adults.

The digestibility of soy-flour in humans is lower than digestibility of animal protein. However, the values of soy-protein isolate approach the digestibility of foods of animal origin. The biological value, representing the amount of absorbed nitrogen retained in the body, in case of soybean is higher (75 percent) than cereals (55 to 70 percent) and legumes (40 to 60 percent).

Carbohydrates

The major carbohydrates are sucrose, raffinose and stachyose. Sucrose is used by humans as an energy source. Raffinose and stachyose are not digested and absorbed and, therefore, have no nutritive value. These two sugars are fermented into carbon dioxide and hydrogen by intestinal micro-organisms in the large intestine and result in flatulence.

In soybean, 90 percent of lignin and 60 percent of the hemicellulose are located in the cotyledon. Forty percent of the hull material is fibre. Most of this hull fibre is cellulose (75 percent).

High fibre diets result in increased stool volume, softness and water holding capacity, decreased transit time and a reduction of diverticular disease. Foods made from whole soybeans are higher in fibre than those made from dehulled beans.

Fats

Fats provide the concentrated form of energy. The average oil content of soybeans is 20 percent. The distribution of saturated and unsaturated fats is 15 percent and 85 percent, respectively. Soy-oil is excellent for use in human diet because of (i) the high ratio of unsaturated to saturated fats and (ii) the high content of the essential fatty acids, linoleic and linolenic acid. (Essential fatty acids cannot be synthesized by humans and thus, must be consumed from the diet).

Advantages

Soybean oil has the following advantages and disadvantages compared to other vegetable oils:

- A high level of unsaturation is present.
- The oil remains liquid over a relatively wide temperature range.
- The oil can be hydrogenated selectively for blending with semi-solid or liquid oils.
- The partially hydrogenated oil can be used as a pourable, semi-solid oil because of the relatively low levels of palmitic acid which, in higher concentration, causes a plastic solid to form.
- The oil can be processed readily to remove phosphatides, trace metals and soaps, thereby improving stability.
- Naturally occuring anti-oxidants (tocopherols) are present and are not completely removed during processing.

Disadvantages

- The phosphatides present in relatively large amount i.e. about 2 percent must be removed during processing.
- The oil contains 7 to 8 percent of linolenic acid which is responsible for flavour and odour. However, partial and selective hydrogenation can be carried out easily to lower the linolenic acid concentration to below 3 percent with greatly improved stability.

Digestibility

In normal individuals, the usually dietary fats and oils are readily absorbed. Soybean oil and partially hydrogenated soy-oil are over 96 percent absorbed. The main factor affecting the digestibility of fat is its melting point. If the melting point of a fat exceeds approximately 50°C, the fat is less absorbed. Presumably, poor absorption occurs because the fats cannot be well emulsified and exist in micro-crystalline form rather than as micelles.

Metabolic Studies

Long-term rat feeding studies, with partially hydrogenated soybean oil, did not have any effect on growth, longevity

or reproduction. However, results from human studies are conflicting. The predominant evidence indicates that partially hydrogenated soybean oil does not significantly raise the plasma cholesterol, phospholipids or triglyceride levels. Increase in blood lipids levels induced by other hydrogenated oils were generally small and probably would not have a significant impact on the development of arterial lesions in normal individuals.

Minerals and Vitamins

As much as 100 gram of soybeans may meet 66, 77 and 120 percent of recommended daily allowances of magnesium, phosphorus and iron, respectively. In soybeans, iron and zinc have been extensively studied with regard to human nutrition. Results of a long-term human feeding study indicate that soy-protein — based food do not adversely affect calcium, iron and zinc status of adults. An adult can meet 95 percent, 48 percent and 47 percent of his daily requirements of thiamine, pyridoxine and folic acid, respectively.

Anti-nutritional factors

The anti-nutritional factors from soybeans have been classified on the basis of their sensitivity to destruction by heat. Research has shown that normal heating of soybeans destroys most of anti-nutritional factors. The heat labile factors are protein in nature which are denatured during cooking. Trypsin inhibitors are the most important anti-nutritional factors.

Trypsin Inhibitors

Trypsin inhibitors (TI) are probably the most widely distributed proteolytic inhibitor of enzymes. They inhibit the action of trypsin, one of the most important digestive enzyme produced by the pancreas. Soybean TI have been shown to inhibit bovine, porcine, ovine and human trypsin.

It has been found that 25, 15 and 7.5 minutes boiling in water were necessary for destruction of TI activity in unsoaked beans, beans soaked in water for 12 hours, and dehulled beans soaked for 12 hours.

Most researchers feel that rat can tolerate and show maximal growth from soy-protein with 80 percent reduction of TI. Total destruction of TI is impractical because excessive heating begins to destory lysine, lowers PER and reduces protein dispersibility and functionality.

Hemagglutinins

They have the unique ability to clump (bind together) or agglutinate red blood cells. This could at least decrease the oxygen carrying capacity of the blood and, at worst, cause a stroke or heart attack. These compounds were first found in legumes 70 years ago. Forty-five minutes boiling of dry whole soybeans is required to completely destroy hemagglutinins. However, as with the TI, complete destruction is not required to provide a safe food. Recently, it has been demonstrated that soybean hemagglutinins play a relatively minor role in the deleterious effects of unheated soybean flour.

Goitrogenic Agents

Rats fed on raw soybeans develop an enlarged thyroid gland (goiter). This can be easily overcome by heating the soy product during processing or adding iodine to the diet. There have been reported cases of goiter in human infants fed on soy-milk.

Saponins

These are said to inhibit chymotrypsin action in digestion of foods. This is a relatively unimportant anti-nutritional factor.

Flatulence Factors

Soybeans are quite high in the mono-saccharides raffinose (1 to 2 percent) and stachyose (5 to 8 percent). These sugars cannot be absorbed by man and, therefore, move to large intestine where they are fermented by micro-organisms. As a result of microbial action, gas (flatulence) is produced that can cause cramps and diarrhoea can occur. Since these sugars are very soluble, these flatus producing factors can be largely removed during blanching or filtration of soy-protein.

Phytic Acid

Phytic acid, the hexaphosphate of myoinositol, has great binding effect due to its structure. Phytate (mineral salt of phytic acid) concentration in typical whole grain cereal and oilseeds ranges from 1 to 5 percent. Soybeans and soybean products contain 1.5 to 2.5 percent phytic acid. Current literature points to very poor mineral bio-availability to animals from soybean products. The reduced availability of zinc, iron, calcium and other minerals is

probably due to chelation of these minerals to phytic acid, fibre or other soy constitutents. The low availability of minerals in soy could be corrected either by mineral supplementation or more simply by utilizing food processing techniques that optimize mineral bio-availability.

UTILIZATION OF WHOLE SOYBEAN

The diet of millions of people in various parts of the world is deficient in protein and calories. At present, one of the best answers to this shortage is whole soybeans.

The whole soybeans provide not only protein of good quality but also are an additional source of energy, which is required to utilize protein, as well as essential fatty acids, vitamin and minerals that are needed in the diet.

Problems

Although soybeans are truly excellent for improvement of diet, there are a number of difficulties encountered in using the products at home. The following are some of these problems:

- Soaking with water of poor quality and high ambient temperature results in rapid deterioration and spoilage because of the growth of micro-organisms.
- The requirement for long cooking time causes wasteful use of fuel and discourages many housewives from using soybeans.
- Cooked whole soybeans alone do not have great appeal and improper treatment catalyzes lipoxygenase activity which results in poor acceptability.

INTSOY Concept

The INTSOY and the food scientists of University of Illinois developed a basic concept in 1970 to control the processing factors. The main points are:

- To inactivate lipoxygenase enzyme (with heat) before it is allowed to develop off-flavour and off-odour.
- To destory all anti-nutritional agents (with heat) during processing of whole (raw) soybeans into soy-products.
- To tenderize soybeans tissue (with baking soda) to the extent required for the specific human food products.

Using this three-faceted concept, it is possible to cook whole soybeans free from anti-nutritional factors, beany flavour, conserving time and energy.

Quality of Soybean for Direct Food Use

Dry whole soybeans must be free from foreign material such as pods, stems and stones. Crushed beans and splits should be removed as far as possible. However, it is essential to use mold-free soybeans. Moldy beans affect flavour and odour drastically and may contain dangerous toxins. In short, soybeans as direct food should be free from all types of defects and should be golden or yellow in colour. Field varieties grown for oil extraction are suitable for preparation of soybean food products. Vegetable varieties of soybeans have not been found to be superior to general field varieties.

Soybeans as Supplementary Proteins

Because of their nutritional characteristics, soybeans and their products play a vital nutritional role in food systems. The protein quality of a soy-cereal food is substantially better than the quality of products prepared solely from soybeans and should be as good as milk protein. Both the cost and acceptability of a food combination could be substantially improved. The protein quality of maize, rice and wheat is increased two-fold and not only does protein quality increase but total protein is also enhanced. Studies on rats indicated that nutritive value of wheat flour supplemented with defatted soy-flour was maximum and was comparable to milk protein. Thus, especially in countries which are short of protein, human consumption of whole soybean should be encouraged. Its products are also good for infants, children and adults alike.

Soy-milk

Soy-milk has been known in China for centuries. It is mostly produced in homes and sometimes on cottage scale. It seems that the population accustomed to the taste of cow/buffalo milk is not much in favour of soy-milk due to its taste. However, by blending the product with cow/buffalo milk or malted preparation, it may be possible to make it acceptable.

According to the PAG Bulletin (1972), the population of Africa, Asia, Latin America and the Middle East have a higher

incidence (50 to 100 percent) of milk intolerance, as compared to European population (1 percent). Thus, for those people who are intolerant to cow milk, a substitute such as soy-milk is needed. The composition of soy-milk, human milk and cow milk is given in Table 5.

Table 5. Chemical composition of soy-milk, human milk and cow milk (100 g)

Component	Soy-milk	Human milk	Cow milk
Water, g	92.0	87.5	87.0
Calories	37.0	67.0	67.0
Protein, g	3.0	1.4	3.3
Fat, g	2.0	3.8	3.6
Carbohydrate, g	2.0	6.8	5.4
Ash, g	0.7	0.2	0.7
Calcium, mg	21.0	32.0	178.0
Phosphorus, mg	48.0	15.0	80.0
Iron, mg	1.2	0.1	0.5

INTSOY (1976) Expanding the use of soybeans series number 10.

Soybeans as Animal Feed

When soybeans are crushed and extracted to remove the oil, the residual meal is a valuable feed with enhanced protein content (relative to the whole bean) for poultry and livestock production.

Probably the single-most important factor in the soybean success story is the amount of high quality protein meal produced at 1255 lb per acre average, a quantity greater than any other commercial oilseed.

Soybean is the largest single source of supplemental protein in the U.S. livestock industry. Today, most of the soybean used for livestock feeding is processed by the solvent extraction method, which removes all but about 0.5 percent of the oil. The remaining soybean meal contains 43 to 50 percent crude protein, approximately 2,900 Kcal of metabolizable energy per kg and 2.7 — 3.5 percent lysine.

However, soybean must be heat processed to make it an acceptable feed for animals. Raw soybeans contain the enzyme urease, which is a problem for cattle on urea supplements, and anti-trypsin, a powerful growth inhibitor affecting poultry. Both these factors are destroyed when soybean meal is heated to 110°C following extraction. Both under-heating and over-heating reduce the feeding value. When the meal is under-heated, the digestibility is reduced and growth rate and egg production are depressed. The pancreas also increases in size. Over-heating tends to produce protein (amino acid) complexes with carbohydrates that are not digested.

Among factors that favour the use of soybean meal in poultry diets is its high content of the amino acids-lysine and tryptophan. It is higher in these two amino acids than most of other plant proteins. Since maize protein is deficient in these two amino acids, the two feedstuffs complement each other in providing a balance of essential amino acids.

Ground and heated whole soybeans (unextracted) can be fed to poultry when it is economical to do so. This product is lower in protein and higher in energy than soybean meal.

From the international perspective, scientists and those in food industries have much to gain from pooling their technologies and perceptions to find out where the soybean fits into the food chain. Soybean should find its proper place in the farming system of the producer and in the combination of food uses of the consumer. Its special qualities ensure for it an important role in the world faced with expanding demands for both proteins and calories.

Diagnosing nutritional disorders in crop plants

*MOHAMMAD SHARIF ZIA AND MOHAMMAD BISMILLAH KHAN**

The growth and productivity of crops, pastures and livestock is frequently limited under practical farming conditions due to deficiencies or toxic excesses of various mineral elements and, in some cases, the success or failure of an agricultural enterprise will depend on the extent to which it has been possible to restrict these deficiencies. Hence, it is imperative for an agricultural scientist to identify such problems when they occur and, on the basis of his understanding of soil and plant factors involved, he must devise corrective measures that are technically sound and economically viable.

In this article, emphasis has been laid on the methods of diagnosing nutritional disorders of crop and pasture plants, since accurate diagnosis is an essential prerequisite to the development of efficient and practical solutions to nutritional problems.

Many techniques are available for investigating nutritional disorders and it is necessary to employ more than one technique to discover the cause of a field problem.

SIMPLE OBSERVATIONS AND USE OF LOCAL KNOWLEDGE

Geology and Soil Type

Some nutritional disorders are more likely to occur on certain soil types than others. In young soils, the chemical composition of parent material may be of particular importance, whereas in older soils, the action of various soil farming factors may be of over-riding importance. In either case, the information from geological surveys, soil surveys, profiled descriptions and soil fertility studies should be considered.

Vegetation

In the early stages of land development, the type of native vegetation may yield valuable clue to the nutrient status of the soil. Indeed in reconnaisance soil surveys, it is not uncommon to use the dominant natural vegetation as an early means of differentiating the soil within a region. In some cases, certain species are sufficiently specialised in their adaptation to occur only on certain types of soil. For example, the occurence of *Neptonia amplexicaulis* indicates soils of high selenium content. Hence, by careful observation of the vegetation, it is sometimes possible to map the occurence of some soil properties without resorting to costly programmes of soil sampling and chemical analysis.

SOIL ANALYSIS AND SOIL TEST

Soil analysis can be used to give information on the likelihood of encountering various types of nutritional disorders, and where the tests have been thoroughly calibrated for the particular soil, it may be possible to estimate both the degree of nutrient deficiency likely to be encountered and the approximate amount of fertilizer needed to correct the deficiency.

Nutrient values regarded as adequate will vary with the type of soil, the crop, the rainfall of the region, the method of chemical analysis and many other factors. Where the researcher does not have access to a soil testing survey, he may make use of various simplified rapid tests.

* *National Agricultural Research Centre, Islamabad*