An improved soy-processing technology to help alleviate protein malnutrition in India

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A small-scale soybean-processing technology has been developed that will produce both high-quality edible oil and protein meal for human consumption. This technology is attractive as an alternative to solvent extraction processing in India because it could facilitate the consumption of domestically produced protein-rich soy products and aid in alleviating the widespread protein malnutrition in the country. At present a high percentage of India's soy protein is exported in the form of animal feed and textured vegetable protein.

Nutrition and pulse production in India

Cereals and pulses are the major sources of protein in India because animal protein is expensive and a large part of the population is vegetarian. Also, a high population density implies that using plant rather than animal protein is desirable, because the intermediate processing of plant protein by animals wastes land and energy [1]. However, the protein quality of both cereals and pulses is inferior to that of animal products because of their less favourable patterns of essential amino acids . The respective protein contents of cereals and pulses are complementary, as each provides essential amino acids that are lacking in the other. The protein quality of a cereal-pulse combination is thus better than that of cereals or pulses alone.

The lopsided growth of agricultural production in favour of cereals over pulses in recent years has resulted in a severe imbalance in the ratio of the two (table 2), leading to a deterioration in the quality of available protein. A recent study [1] hypothesized that there is potential for increasing pulse production in India both by intensifying the use of land by cultivating short-season pulses on land that is otherwise fallow between the rabi (spring) and kharif (autumn) crops and by introducing higher yielding varieties of green gram and black gram that are resistant to yellow mosaic virus. Up to the early 1980s, however, increases in pulse production were small, and future increases are expected to be moderate, because improvements in varieties of pulses have not achieved the substantial increases in yields that improvements in cereal varieties have, as evidenced by the low growth in pulse production relative to cereals (35% versus 199% from 1950/51 to 1985, table 3), and, despite the large increase in cereal production, per capita calorie availability still falls short of the requirements (table 4) and it may not be advisable to divert land from cereal to pulse production since cereals are an important source of energy. Not surprisingly, the price of pulses has increased much more than that of cereals (986% versus 380%, table 3), making it difficult, especially for lower-income groups, to eat a balanced mix of pulses and cereals. Therefore, to help to alleviate protein malnutrition, it is necessary to make the best possible use of the protein sources presently available.

TABLE 1. Essential amino content of various foods. and requirements (grams per 100 grams of protein)

	Lysine	Tryptophan	Phenylalanine + tyrosine	Methionine + cystine	Threonine	Leucine	Isoleucine	Valine
Cereals								
wheat	2.72	1.12	7.37	3.68	2.88	6.57	3.52	4.48
rice	3.69	1.28	9.46	3.85	3.69	8.01	4.81	6.09
maize	3.21	0.64	8.50	3.53	4.49	11.55	3.85	4.81
sorghum	2.39	1.12	7.66	3.03	3.35	14.05	4.31	5.43

Pulses								
gram	7.05	1.12	8.65	2.56	3.53	9.29	5.13	4.97
red gram	7.68	0.64	9.45	1.92	3.20	7.20	4.00	4.16
green gram	7.36	0.96	7.20	2.24	3.20	8.16	5.60	5.12
black gram	6.40	1.12	7.20	2.72	3.52	8.00	5.44	4.96
soybeans	6.40	1.28	8.16	2.88	3.84	7.68	5.12	5.12
Animal products								
fish	8.30	1.04	7.56	3.85	3.56	6.96	5.33	5.19
eggs	7.05	1.44	9.77	5.61	5.12	8.33	6.57	7.21
meat	8.16	1.28	7.36	3.68	4.64	7.68	4.96	5.12
milk	7.97	1.43	9.88	3.35	4.46	9.56	5.42	6.38
FAO suggested								
levels	5.50	1.00	6.00	3.50	4.00	7.00	4.00	5.00

Sources: Ref. 2. table 4: ref. 3.

TABLE 2. Net availability of cereals and pulses per capita in India (grams per day), 1951-1985

	Cereals	Pulses	Ratio of cereals to pulses
1951-1955	354.3	66.3	5.34
1961-1965	398.0	60.3	6.60
1971-1975	394.1	43.5	9.06
1981-1985	410.6	38.7	10.61

TABLE 3. Production and price indices of cereals and pulses in India, 1950/51-1985

	Production index		Price index	
	Cereals	Pulses	Cereals	Pulses
1950/51	53.8	81.6	53.3	42.1
1960/61	82.6	112.3	51.2	42.1
1970/71	114.1	104.4	100	100
1980/81	143.1	95.8	195.1	323.3
1985	161.1	110.2	255.6	457.1
1950/51-1985				
increase (%)	199	35	380	986

a. 1969/70=100.
b. 1970/71= 100.

TABLE 4. Calorie availability per capita in India (kilocalories per day). 19501980

	Pulses	Wheat	Rice	Coarse cereals	Other foods	Total
1950	183	188	569	332	378	1,650
1960	202	235	639	400	434	1.910
1970	169	296	655	349	516	1,985
1980	120	380	683	306	567	2.056

Source: Ref. 4.

An important source of protein that has not been taken adequate advantage of is soybeans. With more than 40% good-quality protein, soybeans properly utilized can help India to alleviate protein malnutrition. Soybean production in India is substantial and economically significant, especially in the states of Madhya Pradesh and Uttar Pradesh. One recent report [5] showed that soybeans were more profitable than competing crops in these states, which may account for part of the rapid growth in their production (table 5). This trend is likely to continue. Given their profitability and their high level of protein relative to competing crops, one might speculate that the protein deficiency created by the slow growth in the production of pulses could be made up by soybeans. In spite of the need for protein sources other than cereals, however, India exports protein-rich soybean meal (50% protein). Total exports reached 400,000 metric tons in 1984 from just over 100,000 metric tons in 1980.

TABLE 5. Production of soybeans in India (thousands of metric tons), 1971 /72- 1983/84

	Madhya Pradesh	Uttar Pradesh	Other states	Total
1971/72	-	-	-	14
1975/76	-	-	-	91
1978/79	232	60	1	293
1980/81	350	84	12	446
1981/82	500	100	11	611
1982/83	358	117	15	490
1983/84	600	105	25	730

Soybean processing

Soybean processing in India emphasizes the extraction of oil. Existing technologies are either large-scale solvent extraction plants or small expellers, neither of which produces good-quality products for human consumption. Large-scale solvent extraction processing for oil at port cities produces a protein-meal byproduct that is not suitable for human consumption. The foreign demand for this meal is far greater than that generated by India's small commercial livestock industry.

Mechanical expellers are commonly used in many developing countries to avoid the high investment required for solvent extraction. When they are used, the soybeans first need to be dry-heated at a high temperature (116-132 °C) in order to increase oil recovery and reduce the level of antinutritional components in the beans. Often several passes of the beans through the expellers are required to obtain an oil yield of more than 50%. In the process, the quality of both the meal and the oil is affected by overheating, and the cake that is produced is not very well liked by consumers.

The fact that neither solvent extraction nor mechanical expelling produces meal suitable for human food suggests that a technology gap in processing soybeans may be impeding the use of soy protein to alleviate protein malnutrition. There is a need for a technology that will contribute to the use of domestically grown soybeans within the country.

An alternative technology

An alternative processing method developed by the International Soybean Program (INTSOY) at the University of Illinois has the potential to eliminate this technology gap. It involves replacing dry heating by extrusion cooking of the beans before mechanical expulsion of the oil. Extrusion cooking uses the high heat generated by friction under pressure to break down the oil-bearing tissues of the beans, thereby significantly increasing their oil yield when they are passed through an expeller. In experiments it has been possible to extract approximately 70% of the oil on one pass without scorching. Scorching is prevented because the total dwell time for this process is only 30 seconds. This high-temperature, short-time treatment helps both in retaining nutritional value and in reducing the antinutritional trypsin-inhibitor factor by as much as 90% [6].

In this extrusion-expelling method, the extrudite is in a semi-fluid state and is fed immediately into the expeller. The recovery of oil is directly related to the temperature of the extrudite [6]. Therefore, preventing heat loss during the transfer of the extrudite from the extruder to the expeller increases the level of oil recovery.

Oil obtained by this process is of high quality, is free of beany flavour, and remains stable for long periods of time. Samples have been stored at room temperature for more than a year with no indication of rancidity. One highly desirable feature is that the oil does not require further refining, making it suitable for low-income countries where there is little refining of vegetable oils.

The meal obtained contains 50% protein and 6% residual oil, with a 90% deactivation of trypsin inhibitor [6]. It can easily be ground in conventional mills. Whole soybeans cannot normally be ground into flour using standard plate and hammer mills because of their high oil content. Since the meal contains only 5%6% oil after extrusion cooking, which in principle serves as coarse grinding of the beans, and mechanical expulsion, fine grinding is possible with less power. The meal can easily be used in the nutritional fortification of wheat flour.

The meal from this new process can also be used for protein fortification programmes, which the Indian government had traditionally favoured. This type of programme can have a substantial positive effect on the nutrition standards of vulnerable segments of the population. In protein fortification programmes the "growth of young children on soy protein or lysine fortified flour is quite good, even when fed at a relatively low percentage of protein calories" [7]. Therefore, with the continually increasing production of soybeans in the country, this new technology offers the possibility of at least preventing further worsening of the cereal: pulse protein ratio, if not improving the situation.

Extrusion cooking is already used in India and many other countries in Asia, but not for extracting oil. The use of extruders has increased significantly in recent years as they have become available commercially in a wide range of models and sizes. Jansen and Harper [7] have noted that the high-temperature, short-time processing provided by extrusion cooking has many benefits, including the deactivation of the antinutritional factors in raw oilseeds. In a number of developing countries. weaning foods and cereal-soy blends for school programmes have been produced by this method. Most extrusion cooking makes full-fat products, as the oil is not expelled.

Since India is deficient in both edible oil and protein, extrusion cooking of soybeans followed by mechanical expelling of the oil has practical application with advantages over both solvent extraction processing and current extrusion cooking technology, which does not produce oil.

Assessment

Experiments at INTSOY continue in order to establish recommendations for the commercial application of this technology. A detailed cost analysis is therefore not possible at this stage. The data in table 6, however, using 1986 prices, suggest that the extrusion-expelling technology can yield higher returns per unit of soybeans used. This elementary analysis assumes that the meal obtained by extrusion cooking and mechanical expelling is ground into flour and sold as an additive to wheat flour; the soy flour is therefore assumed to take on the price of wheat flour, Rs 375 per quintal (100 kg). The soy meal from solvent extraction is priced at Rs 200 per quintal, the average of international and domestic prices of soy animal feed. The total return per eight-hour day from the extrusion-expelling technology for a plant with a capacity of one-half ton per hour would be Rs 24,160, or Rs 2.540 more than that from solvent extraction, which would be enough to cover the wages of any additional workers needed for operation.

Extruders generate heat by friction, eliminating the need for an external source of heat such as is necessary in conventional expelling. Moreover, with extrusion cooking, the throughput of the expeller increases by as much as three times (the throughput of a Chinese expeller increased from 39 kg to 125135 kg [6]), which reduces the power requirement for the expeller by as much as 67%. The energy saved by the elimination of dry heating and the reduced power requirement of the expeller can easily compensate for the power requirement of the extruder.

This analysis does not include fixed costs because the data are not available. Judging from the calculation of the returns alone, however, it would appear that this technology may have profitable applications in India.

Summary and policy implications

Severe protein malnutrition, the expense of animal protein, religious beliefs, and high population density necessitate an emphasis on increasing the vegetable sources of protein in India. However, vegetable protein is of lower quality than animal protein because of inadequate quantities of one or more essential amino acids. Combining cereals and pulses, the important sources of protein in India, in proper proportions greatly improves the quality of the resulting protein, but at present pulses are not available in India in the proportion to cereals that will maximize protein quality. This situation has worsened over the years and emphasizes the need for effective use of the available protein sources.

Proper use of soybeans, which contain around 40% protein, can help ease the problem. Domestic production of soybeans has increased rapidly in the past ten years and is likely to increase further, but current processing technology does not produce meal for human consumption. The new technology developed by INTSOY can be very helpful in this regard.

The government of India and development organizations should encourage adoption of this technology for new plants and plants with expellers. Providing credit and extension services and steering government nutrition programmes towards this technology will facilitate faster adoption. INTSOY hopes that it can be applied in suitable developing countries in the near future.

TABLE 6. Returns per 100 kg of soybeans from soy oil and cake produced by solvent extraction and by extrusion and expelling

	Solvent extraction			Extrusion and expelling		
	Yield (kg)	Price per kg (Rs)	Return (Rs)	Yield (kg)	Price per kg (Rs)	Return (Rs)
Oil	20	19	380	15	19	285
Cake	80	2	160	85	3.75	319
Total	100		540	100		604

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