Isolated soy protein and its use in beverages

Since 1945, total world production of soybeans has risen dramatically from fewer than 15 million metric tons to more than 100 million metric tons in 1990. The expanding market for soybeans has been principally for high-protein supplements for use in animal feeds and for soybean oil for food uses. Soybean meal is primarily used as a high-protein supplement for poultry, pigs, and cattle. The demand for soy protein products in human food applications has been growing. However, less than 5% of the total supply of soybean protein is used for such applications. The common field variety of soybean used in food application is spherical in shape and yellow in color. There are approximately ten varieties grown in the United States, mostly in the Midwestern Corn Belt. These are the basic raw materials for the production of protein products for food and feed applications.

Soybean composition
Soybeans contain approximately 42% protein, 20% oil, 33% carbohydrates, and 5% ash, on a moisture-free basis. The raw materials for protein products derived from soybeans for human consumption are U.S. No. 1 and No. 2 grade soybeans. Proper handling and cleaning of the soybeans are important in maintaining a high-quality raw material. Soybeans should be stored at a moisture content of less than 12%, which helps maintain them in a stable condition; soybeans may be stored for up to one year. At the time of processing, the beans are cracked and dehulled. The hulls are removed and used in animal feed. The cotyledons are broken into six to eight parts to produce thin particles from which the oil can be extracted easily. The most common oil extraction method in commercial operations uses hexane as the solvent. The products resulting from this oil extraction system are crude soybean oil and defatted soybean flakes. After desolventization, the defatted soybean flakes can be further processed into food ingredients. Defatted flakes, on a moisture-free basis, contain 55% protein, 3% residual oil, 6% ash, and 36% carbohydrate.

The carbohydrate component contains 15% soluble carbohydrate and 21% insoluble carbohydrates. The soluble carbohydrate fraction of the dehulled, defatted soybean flakes is

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composed mainly of sucrose, raffinose, and stachyose. Raffinose and stachyose have been implicated as the flatulence factors of soybean products, such as soy flour. These oligosaccharides are not digested in the small intestine and are thought to be fermented in the lower intestinal tract, thus producing gas, distension, and discomfort. The insoluble carbohydrate fraction is primarily the cell wall structure of soybean. Its primary components are hemicellulose, cellulose, and pectin-like substances.

“Soy flour” and “soy grits” are terms referring to specific particle sizes. The particle size of soy grits is usually greater than 100 mesh, whereas the particle size of soy flour is usually smaller than 200 mesh.

Soy flours
In general, there are three categories of defatted soy flour: white soy flour, cooked soy flour, and toasted soy flour. These differ mainly in the amount of heat used on the product during the desolventizing process. The differences lie in the types of desolventizer used to remove the solvent from defatted flakes. Usually, the uncooked or white soy flour will have higher solubility and increased levels of trypsin inhibitor, whereas the cooked and toasted soy flours will have reduced solubility and decreased levels of trypsin inhibitor activity. The toasted soy flour will have a nutty flavor.

Soy protein concentrates
The defatted soy flakes, or soy flour, is the base material for the manufacture of textured soy flour products, soy protein concentrate, and isolated soy protein. Soy protein concentrate is defined as the product prepared from high-quality, sound, clean, dehulled soybeans by removing nearly all nonprotein components to produce a product containing not less than 90% protein on a moisture-free basis. Isolated soy protein is the purest form of soy protein commercially available. The process for producing isolated soy protein involves the use of defatted soybean flakes with high protein solubility. The soy flakes are aqueous extracted to yield a soy milk slurry. The proteins and soluble carbohydrates are solubilized and then the residue, which is primarily the insoluble carbohydrate fraction of the defatted flakes, is separated by centrifugation. The extract is then adjusted to pH 4.5 with food-grade acid. The major protein fraction then precipitates and is called protein curd. The soy whey includes many of the flavor, color, and antinutritional factors that are present in the soybean. It is not recovered for commercial purposes. Protein curd is washed, purified, and spray dried to produce the isoelectric form of isolated soy protein. Protein curd usually is neutralized with sodium or potassium hydroxide to pH 7.0. The neutralized isolated soy protein is the most commonly used form.

Isolated soy proteins are manufactured to provide a variety of functional properties. Based on their functional properties, specific isolated soy protein can be selected for a specific food application. Some of the functional or physical properties involved in such selections include dispersibility, water absorption, solubility, viscosity, emulsification, and gelation. The functionality of the isolated soy proteins may be altered by mechanical, physical, and enzymatic processing methods. The primary product benefits of isolated soy protein are economy, functionality, and nutritional properties.

Determining protein quality
A committee of world-renowned experts has recommended that a variant of the chemical score method be adopted worldwide for use in assessing protein quality for human consumption. There are three main elements to their proposal:

- The requirements of human beings for indispensable amino acids should be as published by the Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU) in 1985, and the requirements of the 2–5-year-old child should be accepted. Apart from the human infant, 2–5-year-olds have the highest protein requirements and should therefore set the minimum pattern. (Infants’ special requirements are satisfied only by the amino acid pattern found in human milk.)

  The protein in question should be analyzed by generally accepted and accurate methods, currently widely used in amino acid determination, in order to establish the pattern of essential amino acids.

  The availability of these amino acids should be measured using a specially recommended method to measure digestibility, and the amino acid score should be corrected for digestibility. The committee decided that the rat-balance method is the most

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suitable practical method for such determinations wherever human balance studies cannot be used. It proposed that the standardized rat fecal balance method, such as that developed by Eggum or by McDonough et al., be adopted. This method involves the feeding of weanling rats, from a standardized strain, with a known quantity of the test substance in a fixed diet for a given period of time. After allowing time for acclimatization, the comparison is made between nitrogen intake and fecal nitrogen excretion. A protein-free control is run to obtain an estimate of the metabolic endogenous nitrogen not of dietary origin.

The main differences between these recommendations and previous ones are:

- The requirement for essential amino acids for humans is determined by the 1985 FAO/WHO/UNU report for the preschool child.
- Methods of amino acid determination are sufficiently advanced that different laboratories can obtain results with a coefficient of variability less than 10%.
- Convenient animal models are available for determining the digestibility of different proteins, especially the rat balance method.

Based on these conditions, the experts concluded that the protein digestibility-corrected amino acid score (PDCAAS) was the most suitable approach for the routine evaluation of protein quality for human consumption, and should be adopted both officially and universally (Table 1).

### Functional requirements of proteins in beverages

Food proteins vary widely in their functional properties, and care must be taken in selecting the most appropriate protein raw material when developing a beverage formula. The beverage applications area can be divided into two categories: dry powders intended for home mixing with liquid before consumption (milk, fruit juice, or plain water) and ready-to-drink beverages (Figure 1).

**Dry beverage applications.** The two most important physical attributes of protein ingredients in dry beverage applications are dispersibility and powder bulk density. If the consumer has difficulty dispersing the powder in liquid because of excessive lump formation or flotation, then the product will not be convenient. Dispersibility is a function of powder characteristics, including particle size. Powders that have been agglomerated, and possibly instantized by the addition of wetting agents such as lecithin, give good results. Use of powdered ingredients that already have good dispersibility will help avoid the need for these extra processing steps. However, a compromise usually must be made between the very rapid dispersibility possible with larger particles and a sandy, or gritty, mouthfeel. The powder particles must hydrate and swell rapidly after dispersion to give a good, smooth product. Powder particle size controls another important characteristic: bulk density. If the powder occupies too great a volume for a unit weight, fitting enough product into a package of fixed dimensions can be a problem. Similarly, it is of great importance to most manufacturers to be provided with ingredients that can be handled in bulk without excessive generation of dust. Dust extraction equipment is expensive to install, and the need for it can be eliminated by

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**Table 1** Calculation of protein digestibility-corrected amino acid score (PDCAAS) for an isolated soy protein (ISP)

<table>
<thead>
<tr>
<th>Essential amino acid (EAA)</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supro brand ISP EAA profile (mg/g protein)</td>
<td>FAO/WHO 2- to 5-year-old reference pattern (mg/g protein)</td>
<td>Uncorrected amino acid score</td>
<td>Protein digestibility-corrected amino acid score (PDCAAS)</td>
</tr>
<tr>
<td>Histidine</td>
<td>26</td>
<td>19</td>
<td>1.37</td>
<td>1.33</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>49</td>
<td>28</td>
<td>1.75</td>
<td>1.70</td>
</tr>
<tr>
<td>Leucine</td>
<td>82</td>
<td>66</td>
<td>1.24</td>
<td>1.20</td>
</tr>
<tr>
<td>Lysine</td>
<td>63</td>
<td>58</td>
<td>1.09</td>
<td>1.05</td>
</tr>
<tr>
<td>Methionine and cystine</td>
<td>26</td>
<td>25</td>
<td>1.04</td>
<td>1.00d</td>
</tr>
<tr>
<td>Phenylalanine and tyrosine</td>
<td>90</td>
<td>63</td>
<td>1.43</td>
<td>1.39</td>
</tr>
<tr>
<td>Threonine</td>
<td>38</td>
<td>34</td>
<td>1.12</td>
<td>1.08</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>13</td>
<td>11</td>
<td>1.08</td>
<td>1.05</td>
</tr>
<tr>
<td>Valine</td>
<td>50</td>
<td>35</td>
<td>1.43</td>
<td>1.39</td>
</tr>
</tbody>
</table>

a Essential amino acid profile and true digestibility of ISP based on actual analysis by Protein Technologies International, manufacturers of Supro.

b Uncorrected amino acid score = column II/column III.

c PDCAAS = uncorrected amino acid score (column IV) x 97% (true digestibility).

d PDCAAS = 1.00 (lowest corrected amino acid score).
judicious ingredient selection. Isolated soy proteins have been developed with precisely these considerations in view, and bland, smooth mouthfeel products have been produced using them as the sole source of protein.

**Liquid beverages.** In multiphase systems such as liquid drinks, the proteins are called upon to do a number of different things, contributing to flavor, color, mouthfeel, viscosity, mineral suspension, and emulsion stability. The correct choice of isolated soy protein product is vital for the final product's organoleptic characteristics and stability. The key starting point in the production of liquid beverages is the complete hydration of the protein. Proteins with low solubilities will not provide good stability over the shelf life of the product. The proper choice of processing equipment and sequence of processing steps are also keys to success.

The stabilization of fat globules by soluble proteins in the product determines the stability of the emulsion and the extent to which fat separation, or "creaming," will occur. Different protein ingredients have differing abilities to become adsorbed in the fat/water interface, reflecting differing degrees of hydrophobicity and the ability to change conformation at the interface. The choice of product must also reflect these properties. The technology exists to produce isolated soy protein products that provide the optimum solution to these problems, enabling standard processing equipment to be used.

**Recent developments in isolated soy protein technology**

One problem associated in the past with traditional soy-based beverages has been the need to fortify the products with calcium and phosphorus for nutritional reasons. Soluble calcium salts react with the proteins to produce insoluble aggregates, while the use of insoluble calcium phosphates results in sedimentation of the salts and a chalky mouthfeel. A recently patented invention now permits the addition of calcium and phosphorus to isolated soy protein during the production process in such a way that the calcium-to-protein ratio is the same as that of milk. The resulting beverages exhibit no sedimentation of minerals, excellent protein stability, and excellent mouthfeel. Extensions of this same technology, involving combinations of calcium-fortified isolated soy protein and whey, have resulted in a new generation of ingredients that behave in beverage systems much as do skimmed milk solids. Supplementation with vitamins and some extra minerals results in products with high nutritional values without changes in the organoleptic qualities of the end product. These new ingredients are being evaluated by European manufacturers of products for weight-loss programs, sports nutrition supplements, specialized nutritional drink mixes, and extended-milk products.

Soy protein technology has made enormous progress during the past few years, and isolated soy protein products are now available that yield products with excellent consumer acceptability, while exploiting the unique marketing claims made possible by the use of these ingredients. With a huge upsurge of consumer interest in products claiming to be low-fat, low-cholesterol, lactose-free, 100% vegetable, etc., the new generation of isolated soy proteins offers beverage manufacturers an attractive and economical alternative source of protein, and the chance to stay one step ahead in the marketplace.