Advances in the Preparation of Soy Protein and Lecithin Ingredients for Tomorrow's Foods

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Today's food technologist is receiving increasingly pointed directions in the "selection of" and often "minimum amounts of" ingredients to use in the development of new food products. This increasing emphasis by marketing on "label" claims is real and gaining momentum in most market places. Thus, the development of functional foods that are providing customers with new and distinct nutritional choices.

The driving force for the increased direction of the food technologist is that many governments are now allowing health related label claims on food products. These health claims are a result of very clearly and focused research that shows known nutritional benefits. The regulatory environment is well focused on the results of this peer reviewed research. In the USA, FDA has allowed several opportunities for health claims including fiber, soy protein and choline.

This presentation will focus on only two of many functional ingredient options - the soy proteins and lecithin (choline).

Ⅰ. Soy Proteins

At 38% protein, soybeans are one of the richest sources of protein in the plant world. Soybeans are cracked, dehulled and rolled into flakes. When the soybean oil is removed from these flakes, the resulting material is soy protein. There are various types of soy proteins defined by their protein composition as shown in Fig. 1.

Soy flour maintains much of the original composition of the soybean, except for the oil. Soy flour is approximately 50% protein (on a dry weight basis) and 50% carbohydrate/ash. It contains both fiber and soluble sugars. Although soy flour is not typically used in home baking, it is used extensively in the food industry. Soy flour is often textured for use in meat and food applications.

Soy Protein Concentrates range between 65～89% protein. Concentrates retain some of the carbohy-

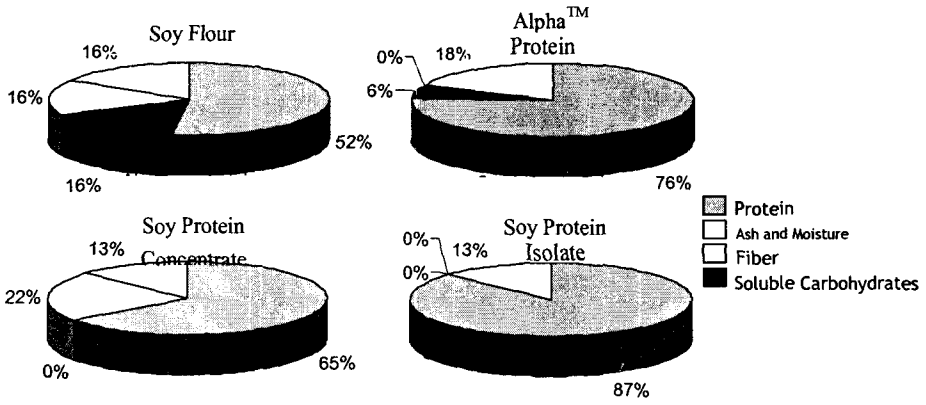

Fig. 1. Composition of soy proteins(as is).

Table 1. Amino acid profiles for various proteins.

Amino Acid Profile	Whey Concentrate	Whey Isolate	Calcium Caseinate	Soy Protein Isolate	Alpha 5800
			g/100g Protein		
Alanine	4.2	5.1		4.3	3.7
Arginine	2.2	2.7	3.8	7.6	6.8
Aspartic Acid	9.2	9.7		11.6	11.1
Cystine/Cysteine	1.8	2.3	0.4	1.3	1.3
Glutamic Acid	16.1	18.6		19.1	17.6
Glycine	1.7	1.8		4.2	3.7
Histidine	1.4	1.7	3.2	2.6	2.4
Isoleucine	4.8	4.7	5.8	4.9	4.3
Leucine	9.1	13.5	10.1	8.2	7.0
Lysine	7.5	9.0	8.3	6.3	6.0
Methionine	1.7	2.2	3.0	1.3	1.3
Proline	2.4	4.6		5.1	4.7
Phenylalanine	5.6	5.2	5.4	5.2	4.5
Serine	4.4	3.9		5.2	4.7
Threonine	6.0	4.5	4.6	3.8	3.7
Tryptophan	0.8	1.8	1.4	1.3	1.4
Tyrosine	2.2	3.8	5.8	3.8	3.2
Valine	4.6	4.9	7.4	5.1	4.5

drate of the soybean (either fiber or sugars). The remainders of either class of carbohydrates are removed and thus the protein increases from 50 up to at least 65%. The carbohydrate component of concentrates adds some functionality to the protein and allows for extruded and textured applications. Such application of the powdered or textured SPC includes processed and whole muscle meats, veggie burgers/patties and other meat analogs. A new type of soy protein concentrate (Alpha^{TM} Protein) retains a portion of the soluble sugars and isoflavones while the soy fiber is removed. Concentrates are now available for use in nutritional and other beverages, bars, baked goods, cereals and other food products.

Soy Protein Isolates are 90% protein (moisture-free) and are used in food applications such as beverages, infant formulas, bars, and powders. The fiber and sugars of soy flour have been removed Soy protein also contains a number of botanical compounds that are important for health. The most well known and most researched of these are the soy isoflavones. It is important to note that not all soy products or even soy protein have significant levels of isoflavones. When the components of the soybean are separated from the oil, isoflavones remain in the protein compartment; however, some of the processes used to remove the carbohydrate component also remove the isoflavones. Soy isolates and flours generally retain the isoflavones, while soy concentrates can vary and provide an isoflavone-rich or -free soy protein option. Table 1 shows the amino acid profile of soy protein compared with various milk proteins.

1. Measurement of Protein Quality

The quality of a protein is judged by its specific composition and how well the protein is digested and absorbed by the body. The highest quality protein is one that provides all the essential amino acids in the proportion needed by humans and is highly digestible. Historically, a number of methods have been used to determine protein quality. Before the 1990s, the protein efficiency ratio (PER) was used in the U.S. to determine protein quality. To obtain a PER, young rats are fed a measured amount of protein and weighed periodically as they grow. PER is calculated by dividing weight gain by the amount of protein consumed.

$$\text{PER} = \frac{\text{weight gain(g)}}{\text{protein intake(g)}}$$

In 1992, the World Health Organization (WHO) issued a statement that the PER method was not accurate to assess protein quality for humans because rats metabolize certain amino acids differently than humans. Thus, a high quality protein for a rat does not equate to a high quality protein for a human. Soon afterwards, U.S. food labeling laws were revised and discontinued the use of the PER method. The current method of assessing protein quality for labeling is the protein digestibility corrected amino acid score (PDCAAS). PDCAAS is based on first calculating an amino acid score (AAS) for each amino acid in the protein. The AAS is calculated by dividing the amount of the amino acid found in the protein by its specific requirement in the human diet.

$$AAS = \frac{\text{Amino acid content of the protein*}}{\text{Amino acid requirement for humans}}$$

*expressed in mg/g of protein

Once all AASs are calculated, the lowest score, which represents the "limiting amino acid," is multiplied by the digestibility factor for the protein, with "1.0" being totally digestible.

In terms of human nutrition, Table 2 shows a comparison of PDCAAS values for soy and milk proteins.

Table 2. PDCASS Values for Soy and Milk Protein

Protein	PDCASS
Whey Protein	1.00
Casein	1.00
Soy Protein Concentrate	0.99
Soy Protein Isolate	0.97

1) Soy Protein Health Claim

In October 1999 the United States FDA finalized the Soy Protein Health Claim linking soy protein and a reduced risk of coronary heart disease (CHD). This allows for a health claim label to be displayed on the front panel of the food item similar to the following. "25 grams of soy protein a day, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease. A serving of (name of food) provides xx grams of soy protein." By definition, a serving must contain at least 6.25 grams of soy protein. This allows for the ingestion of four portions a day. This has given great emphasis to the use of soy proteins in the USA. Presently, this is only for FDA controlled foods versus those controlled by the US Dept of Agriculture. Central soya food scientists have developed many prototype food products that contain at least 6.25 grams of powdered or textured proteins. Meat products are regulated under USDA.

2) Alpha® Soy Protein Concentrates

Central Soya has recently introduced a new soy protein concentrate that does not contain insoluble carbohydrates (fiber) and is very soluble. It is called Alpha SPC and contains~80% protein (mfb). Because of its solubility and very low flavor profile, it is well suited for use with milk protein to make various combination beverages, yogurts or frozen desserts. Additionally, the Alpha protein line has been used alone in products like these. Due to its low flavor profile, high solubility and mouthfeel it is also being evaluated in various protein drinks and for many bar and baked food applications. There is a very significant role for such new ingredients. The unique properties of the Alpha proteins are summarized in Table 3.

Table 3. Alpha 5800 Product Characteristics

* 78% (mfb) protein / Health Claim levels possible
* Identity preserved
* High solubility / stable in solution
* High emulsion capacity / stability
* Pleasant natural soy flavor - easy to flavor
* High quality protein
* Contains phytochemicals (isoflavones)

Ⅱ. Soy Lecithin

Lecithin is a naturally occurring group of phospholipids that is found in nearly every living cell. Though the word lecithin is derived from the Greek lekithos, which means "yolk of an egg," the primary commercial source of lecithin comes from the soybean. The food industry has long recognized lecithin as a lipophilic emulsifier used in products like margarine and chocolate. But lecithin is much more than that. Through specific modification techniques, Central Soya has extended the functionality and physical characteristics of lecithin far beyond their natural limitations to include a wider range of functionalities like wetting dispersion, lubrication, sprayability and ease of handling in dry powder form.

Soybean lecithin is removed from the soybean along with the oil in the hexane extraction step. The lecithin is then hydrated and removed from the crude soybean oil by centrifugation. The hydrated lecithin gums are then dried and processed in various ways to provide a wide array of hydrophilic and lipophilic properties. This is called the hydrophilic-lipophilic balance (HLB). These properties are important in selecting the right lecithin for various applications.

1) Choline - The Newest Vitamin

Choline is a dietary component that is important for cellular structure and a number of cellular processes. In 1998, the United States National Academy of Sciences (NAS) designated choline an essential nutrient and established dietary reference intakes (DRI) for choline which includes a level of adequate intake (AI) and a tolerable upper limit (UL). Table 4 shows the AI and UL for both sexes and various ages as set by the NAS.

2) Why is choline now an essential nutrient?

A number of studies show that human cells grown in culture have an absolute requirement for choline. When cells are deprived of choline they die via apoptosis or "programmed cell death." To be considered an essential nutrient, it must be determined that the substance cannot be made by the body itself in sufficient amounts from other metabolic constituents. In the case of choline, it has been known since 1961, that humans can produce choline via methylation of the phospholipid, phosphatidyl ethanolamine. However, the demand for choline is modified by the methyl -exchange relationships between choline and

Table 4. Choline AI and UL

Group	Age	Adequate Intake mg/day		Upper Limit g/day
		Male	Female	
Infants	0~ 6 mos	125	125	Not known
	7~12 mos	150	150	
Children	1~ 3 yr	200	200	1
	4~ 8 yr	250	250	1
	9~13 yr	375	375	2
	14~18 yr	550	400	3
Adults	19+	550	425	3.5
	Pregnancy		450	3.5
	Lactation		550	3.5

Institute of Medicine, DRI 1998

methionine, folate and vitamin B_{12}. Thus, in order to determine the essentiality of choline, it must be shown that the rate the body makes choline is not adequate to meet the demand when the folate, B_{12} and methionine are available in amounts sufficient to sustain normal growth and function.

A landmark study in 1991 showed that healthy men with normal folate and vitamin B_{12} status fed a diet deficient in choline have diminished plasma choline and phosphatidyl choline concentrations and subsequently develop liver damage. In other words, with the other nutrients being adequate, the body itself is not able to produce choline in quantities sufficient to prevent liver damage and choline is thus "essential."

3) Relationship between Choline and Lecithin

Lecithin is a mixture of a number of phospholipids, which are similar to other dietary fats or "triglycerides" except that instead of three ("tri") fatty acids attached to a molecule of carbohydrate ("glycerol), they have two fatty acids and a phosphorous. A number of other biologically important compounds can attach to this phosphorous molecule including choline-as the vitamin component of the phospholipid, phosphatidyl choline. Lecithin, as phosphatidyl choline, serves as the main dietary source of choline. Lecithin contains about 13% choline by weight.

1. Basic Physiological Roles of Choline

Cell Membranes-choline, as part of phosphatidyl choline provides structural stability for cell membranes and a reserve supply of choline for the body. Choline also acts as a "second messenger" which is the process by which hormones and other substances transmit signals from outside of a cell to the interior. Without choline's action as second messenger cells could not properly grow, replicate or absorb and use nutrients.

Table 5. Choline content of various foods

Food	Choline Content of Standard Portion Size(mg)
Apple	3
Beef Liver	287
Beef Steak	41
Coffee	1
Egg	198
Milk	5
Peanut Butter	11
Peanuts	13
Whole Wheat Bread	2

Methyl Metabolism-choline, folate, vitamin B_{12} and methionine (an essential amino acid) all participate in methyl group metabolism. Methyl groups (CH_3) are components of numerous important biological compounds.

Cholinergic Neurotransmission-choline has a principal role in the formation and release of acetylcholine-a vital neurotransmitter (chemical messenger used by neurons) in the memory centers of the brain (hippocampus and septum).

1) Best sources of choline and lecithin?

Although lecithin and choline can be found in a wide variety of foods; the primary source of lecithin is soybeans. Other foods rich in lecithin are also high in cholesterol and fat, like egg yolks and organ meats like liver. Because many people making healthy dietary changes have decreased fat and cholesterol intake; lecithin intake has decreased in recent years. Table 5 provides a list of lecithin/choline containing foods.

2) Supplement Sources

It is estimated that those consuming western diets consume 6g of lecithin per day-far below the suggested level of intake of 16 to 20g of lecithin per day. Soy lecithin supplements provide an alternative to obtaining lecithin via high-fat, high-cholesterol foods. Although both lecithin and choline are available as supplements; soy lecithin appears to provide a more bioavailable source of choline than do supplements comprised of choline salts. Fig. 2 shows serum choline concentrations following administration of soy lecithin and choline chloride delivering equal amounts of choline and followed over 12 hours. Serum choline concentrations following ingestion of choline chloride peak after one hour and fall steadily afterwards; while serum choline levels after lecithin administration continuously rise for up to 8 hours and remains elevated after 12 hours post-ingestion.

Choline and lecithin have numerous health benefits, some of which have only begun to be explored by the scientific community. It is likely that the recent determination of choline as an essential nutrient will stimulate more basic and clinical research on the specific roles of choline in important biological processes and disease prevention. (References for these and other Health issues are contained in *The Lecithin and*

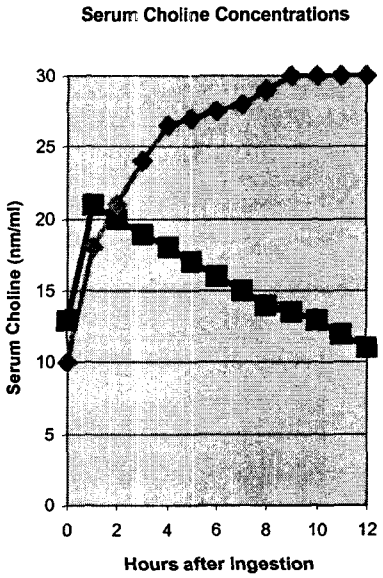

Fig. 2. Bioavailability of Choline Supplements.

Choline Book Copyright 1998 Central Soya)

3) Increased Choline-Soy Lecithin Fractions

In additions to the HLB properties, emphasis today is toward making increased PC lecithin fractions. Typically, liquid lecithin contains 16% PC while deoiled lecithin contains 23% PC. The new liquid lecithin product from Central Soya contains 35% PC and the new deoiled lecithin fraction product contains 40% PC. These products are summarized in Fig. 3.

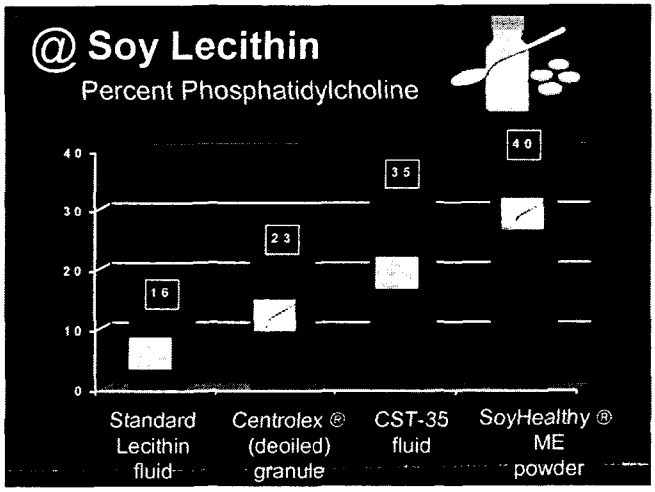

Fig. 3. PC content of several commercial lecithin products.

4. Choline Claim

As Choline is linked to better memory, heart health, liver function and more, on 29 AUG 01, the Food and Drug Administration has cleared the way for new food labels that will enable consumer to identify foods and dietary supplements that provide qualifying levels of choline. The choline claim is the first nutrient content claim to be authorized under the Food & Drug Administration Modernization Act (FDAMA). Thus, consumers who want to incorporate more choline into their diet can look forward to new labeling approvals in the food industry for choline. Food manufacturers can now use "good source" or "excellent source" of choline labels on their products.

To qualify for the "Good source of choline" label claim, a food or supplement must contain 55 mg of choline per serving and 110 mg per serving to make an "Excellent source of choline" claim. These levels are 10% and 20% respectively, of the Adequate Intake level set for choline by the Institute of Medicine.

USA food processors are now in the midst of developing new food products with these labels.

Ⅲ. Summary

As mentioned, new labeling opportunities using the new nutrient content claims for Soy Protein and Choline are providing clear opportunities to develop foods with known nutrient contents.