Physical-chemical properties and consumer attributes of meat-soy food systems

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During the past decade much interest has been focused on the commercial production and utilization of food grade soy protein products for the meat industry. To-date their use has been considered for two basic applications as a functional ingredient in predominately meat systems, and as the basic ingredient for the manufacture of meat-like simulates, either singularly or in combination with meat fibres (Coleman and Creswick, 1966). In the former application, that as a functional ingredient, the protein is used because of its ability to emulsify, stabilize, texturize and hydrate the meat system. In this particular case the nutritional value of the protein is of secondary consideration because of the small quantities used. However, it does contribute to the overall nutritional characteristics of the system. The protein contributes the major portion of the textural matrix of the product when used in the production of meatlike simulates. Likewise, it provides major nutritional elements to the product.

Currently soy protein products are available in three commercial forms: soy flour, soy protein concentrate and isolated soy protein. The proximate analysis and standards for these products are shown in Table 1. Table 2. presents the amino acid profile.

Because of its functional characteristics, isolated soy protein is most often used in the meat industry in the manufacture of emulsion-type products. Similarly, this protein is used as the basic ingredient in the manufacture of spun fibers which are ultimately used in the preparation of meat simulates. Recently, Pearson *et al* (1965), Schut, (1968), and Bezdicek and Allen, (1968), have published data evaluating the functionality of soy proteins, i.e., isolated soy protein, in model emulsion systems. Based on these findings they have questioned the functional value of the proteins in actual meat systems. However, the relationship between data obtained using model systems and actual in-use performance has never been established.

The purpose of this communication is to present data illustrating the physical-chemical properties of soy protein isolate and to relate these characteristics to those of the final products. As soy protein isolates are a heterogenous mixture of proteins and vary significantly in their physical-chemical and functional properties among manufacturers, this paper will limit itself to discussing one specific isolate.[1]

The basic elements of soy protein isolation are quite simple and well known. Defatted flakes produced with minimal heat treatment are extracted with an aqueous medium which varies in pH from near neutrality to slightly alkaline. After separation of the fibrous residue, the protein containing liquor is acidified to pH 4.5 to precipitate the major globulin fraction. The resultant curd is concentrated, washed and separated as a protein slurry. This slurry is either dried as such or is neutralized to pH 7.0 to produce a dispersible, soluble sodium proteinate. (See Fig. 1)

Table 1. *Proximate Analysis of Commercial Soy Protein Products*

	Defatted soy flour	*Soy protein concentrate*	*Isolated soy Protein*
Moisture %	8.0[1] (Max)	8.0	4.9
Protein (N X 6.25) %[2]	50.0[1] (Min)	70.0[1] (Min)	90.0[1] (Min)
Crude Fiber	3.5[1] (Max)	2.9	0.2
Fat %	2.0[1] (Max)	.3	0
Ash %	6.5[1] (Max)	4.7	3.8

1. Standards established by National Soybean Processors Assoc. U.S.A.
2. Moisture free basis.

Table 2. *Amino Acid Composition of Soy Protein Products Essential Amino Acids g/16 g. N*

	Defatted soy Flour	*Soy Protein Concentrate*	*Isolated soy Protein*
Lysine	6.2	6.2	6.0
Methionine	1.3	1.3	1.1
Cystine	1.2	1.6	1.0
Tryptophan	1.4	1.4	1.3
Threonine	4.0	4.3	3.7
Isoleucine	4.6	4.9	4.8
Leucine	7.7	8.0	7.8
Phenylalanine	5.3	5.3	5.5
Valine	4.9	5.0	4.8
Histidine	2.9	2.7	2.5
Arginine	8.0	7.5	7.8

Recently, Catsimpoolas and Ekenstam (1969), using immunological techniques have shown that the heterogeneous globulin fraction contains the proteins glycinin, α -conglycinin, β -conglycinin and γ -conglycinin. Characterization of the globulin fraction by ultracentrifugation (Wolf, 1969) reveals four primary sedimentation fractions; these are tabulated in Table 3 together with some of the physical constants and proposed composition.

Fig. 1. *Schematic diagram showing isolation of globulin fraction.*

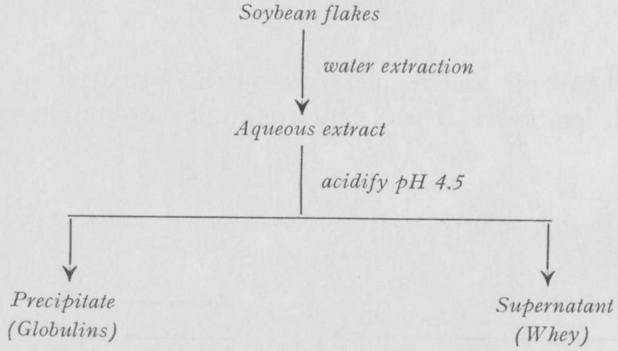

Table 3. *Physical Characteristic of Ultracentrifuge Fractions of Soybean globulin.*

Ultracentifuge Fraction	*% of water Extractable Proteins*	*Proposed Composition*	*Molecular Weight*	*Isolectric Point*	*Sedimentation Constant S° 20 w*	*N-Terminal Residues*
2S	18	α−conglycinin	26 000	—	—	Asp.
7S	27	β−conglycinin γ−conglycinin gycinin-monomer	330,000 210,000	4.9	7.95S 7.92S	Asp, Glu, Ala, Glu, Val, Ser, Try, Leu.
11S	34	dimer glycinin	350,000	5.0	12.25	Gly, Phe, Leu. (1-Leu)
15S	6	Polymers of glycinin	—	—	—	—

Physical-chemical characteristics of isolated protein. Rheological properties

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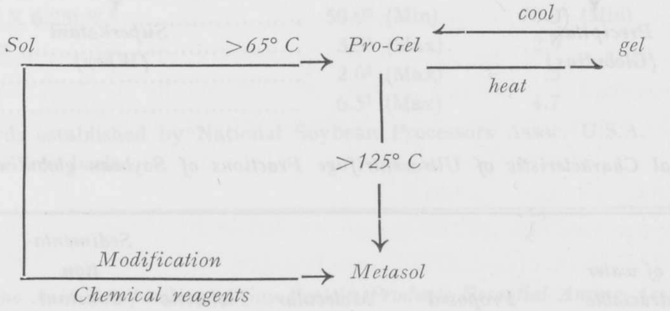
1) PROMINE-D, manufactured by Central Soya Co., Inc., Chicago, Illinois.

Gelation

The ability of isolated soy protein to gel in aqueous media may be an important factor in its ability to contribute to the structural matrix of the meat food system. Extensive studies by Catsimpoolas and Meyer, (1969) and Circle, Meyer and Whitney, (1964) on the rheological properties of soy globulin gels have shown that heating aqueous dispersions of the protein (concentration greater than 8 %) causes a transformation from the sol to progel state, which is characterized by a marked increase in apparent viscosity. A gel of higher viscosity is formed by cooling the progel. The sol — progel transformation is irreversible. However, the gel can be converted into the pro-gel by heating and subsequent cooling. These phenomena are illustrated in Figure 2.

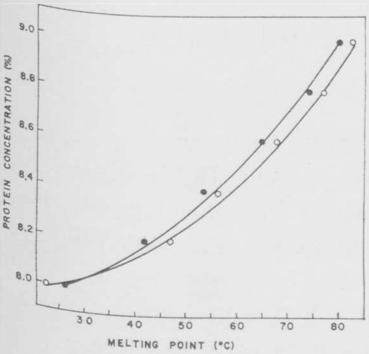
The influence of pH and temperature on the formation of both the pro-gel and gel are significant. These data are graphically presented in Figure 3

Fig 2. *Schematic illustration of rheological transformation of isolated soy protein*

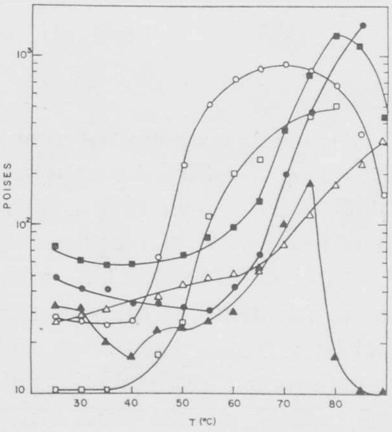


Circle *et al.*, (1964) have reported that concentration of protein and time of heating significantly influenced apparent viscosity of the system. Further data from Catsimpoolas and Meyer (1969) showed that the addition of alcohols with varying aliphatic chain length and degree of branching influence gel viscosity. Apparent viscosity increases with the addition of alcohols with increasing chain length and decreases with the addition of more branched chain alcohols. The addition of lipids to the dispersion causes a change in viscosity. The viscosity was increased by adding lipids with decreasing fatty acid chain length, decreasing length of the polyol chain and decreasing esterification of the hydroxyl groups of glycerol. Saturated lipids produce gels of higher viscosity than did unsaturated lipids. Addition of phospholipids and cholesterol increased apparent viscosity.

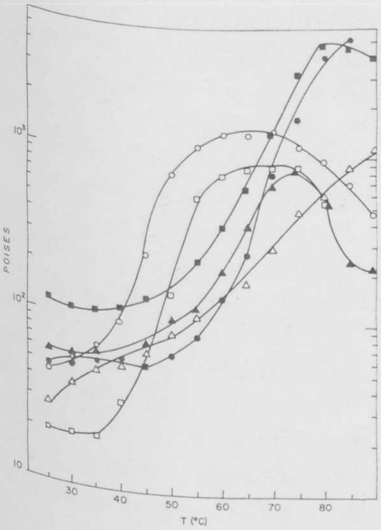
Fig. 3 Graph Showing Influence Of pH And Temperature On Apparent Viscosity Of Aqueous Protein Dispersions



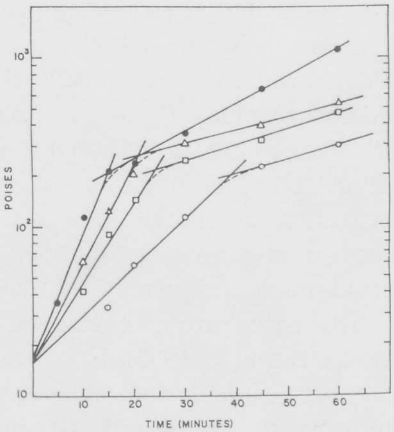
Melting points of soy globulin gels as a function of protein concentration: ●-●, gels aged for 1 hr at 4°; o-o, gels aged for 24 hr at 4°.



Effects of pH and temperature on the apparent viscosity of the progel: 10% soy globulins (w/v): o-o, pH 1; □-□, pH 2; Δ-Δ, pH 6; ●-●, pH 7; ■-■, pH 8; ▲-▲, pH 10.



Effects of pH and temperature on the apparent viscosity of the gel: 10% soy globulins (w/v): o-o, pH 1; □-□, pH 2; Δ-Δ, pH 6; ●-●, pH 7; ■-■, pH 9; ▲-▲, pH 10.



Apparent viscosity of the progel as a function of time and temperature: 10% soy globulins (w/v); pH 7: o-o, 65°; □-□, 70°; Δ-Δ, 75°; ●-●, 80°.

Protein aggregation

Recent studies in our laboratory by Catsimpoolas and Funk, (1969) on the factors influencing the heat aggregation of the 11S component in dilute solution have shown that ionic strength and pH are important variables. Temperature, salt concentration and pH have a significant effect upon protein aggregation. At neutral pH, aggregation is initiated at 70° C.

Hydration

Although very limited quantitative studies have been done on evaluating the absolute hydrating capacity of isolated soy protein, Bezdicek and Allen (1968) have shown that a meat-soy system will hold approximately 100 % more free water than a pure meat system in which water was added in excess. Recent studies in this laboratory have shown that in frankfurters containing equal quantities of total protein, those in which 2 % and 4 % meat protein had been replaced with soy protein, exhibited significantly less free moisture as determined by the method of Grau & Hamm, (1953) than those containing only meat protein. This study indicates that soy proteins have greater hydration capacity than meat proteins.

Emulsification — capacity and stability

One reason isolated soy protein has found ready acceptance in the meat industry is because of its ability to act as an efficient emulsifier. To-date three investigations (Pearson *et al.*, 1965, Schut, 1968, Bezdicek and Allen, 1968) have been published in which the relative functional value of isolated soy protein has been questioned. These conclusions have been based on experiments using model systems. However, in a recent article published by Inklaar and Fortuin, (1969) they were able to show that in actual meat emulsion systems, those containing 2 % soy protein exhibited 0.4 % separable fat, whereas 8.2 % fat separated from the all meat product. Similar observations have been noted in our laboratory. The discrepancy in findings between these studies indicates the questionability of the total relationship between observations obtained in model systems and those obtained on actual meat systems.

The early work of Hansen, (1960); Swift and Sulzbacker, (1963) and Borchert *et al.*, (1965) has demonstrated that in the production of stable meat emulsion systems the stability of the emulsion is derived from the ability of the water and salt soluble proteins to encapsulate the fat globules and form a stable matrix upon heating. If this is the valid mechanism for the formation of stable systems for all proteins, then the data developed using model systems may be related to commercial meat systems. Then the physical-chemical properties proposed by Schut, (1968) for emulsifyers would be valid. Becker, (1968), Kitchener and Musselwhite, (1968) have reported that finely divided powders act as very effective and efficient emulsifying agents in oil-water systems. More specifically, the solids act as stabilizers by preventing the coalescence of the dispersed phase. Accordingly, the chemical nature of the particles is not as significant as their surface properties. The requirements are that the particle size must be small compared to fat globule size, the particles must exhibit a substantial angle of contact at the three phases: oil, water, and air. Also, the particles must not exhibit strong hydrophilic or hydrophobic properties as they would become preferentially soluble in a specific phase.

The type of emulsion produced is dependent in part on which phase preferentially wets the solid (Scarlett *et al.*, 1927). Schulmann and Leja, (1954) have reported that oil in water emulsions are obtained with solids when the contact angle, as measured through the water phase, is slightly less than 90°, indicating that the solid is more readily wetted by water than by oil.

Based on the often-observed phenomena (Williams, 1967, Inklaar and Fortuin, 1969 and Cook, 1969) that soy proteins do contribute significantly to the emulsifying capacity and stability of meat emulsions, it is proposed that the mechanism by which these phenomena are brought about is that in commercial emulsifying equipment the soy protein is so dispersed as to act similarly to finely divided solids. The physical-chemical properties of the soy proteins are such that they can act in this manner.

As there appears to be some disagreement on the performance of soy proteins when evaluated in model and actual systems, it would appear that in model systems the protein is not utilized in a manner in which it acts most effectively as in the case of commercial systems. In all probability, if the techniques of emulsification in oil and water systems were so altered as to allow the soy protein to act as a finely divided powder then the relationship of the findings obtained in the two systems would be grater. However, this mechanism may not be applicable for the soluble fraction of the soy protein.

As can be seen from the data of Catsimpoolas and Meyer (Table 3), soy proteins do significantly increase the viscosity of an aqueous system thus satisfying the requirements postulated by Schut, (1968). However, it is to be remembered that multiple mechanisms may be responsible for the emulsion characteristics of a variety of meat systems.

Williams, (1966) in a series of experiments investigating the influence of processing temperatures upon the stability of canned meat emulsions observed that minimal fat separation occurred if the product was heated to an internal temperature between 70° C and 120° C. This temperature range coincides with the gel-progel-metasol transformations observed by Catsimpoolas and Meyer, (1969).

Likewise, in a recent study using an experimental luncheon loaf formulation of beef chuck and rendered lard, (total protein 14 %, fat 35 %, moisture 48 %) it was observed that if they were processed at high temperature and humidity to reduce cooking time, the all meat sample manifested a processing shrink in excess of 25 % and the emulsion was completely broken. Whereas those samples in which 2 % and 4 % of the meat protein was replaced with soy protein, processing shrinks were 4 % and 2 % respectively. Both products showed highly stable emulsions and were acceptable.

Apart from its functional contribution, the use of soy protein has marked economic advantages. In an experimental frankfurter formulation using beef chuck as meat source (11 % total protein, 30 % fat) with total protein held constant, replacement of 2 % and 4 % of the meat protein with soy protein reduced the cost of the final product by 24 % and 32 %. The yield of finished product, based on meat used, was increased by 16 % and 42 % when 2 % and 4 % soy protein replaced equivalent quantities of meat protein.

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