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Functional Properties of Soy Protein Concentrates and Functional, Nutritional and Sensory Properties of a Corn-Soy Concentrate Cereal as Influenced by Selected Calcium Salts

Charlene James
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To the Graduate Council:

I am submitting herewith a dissertation written by Charlene James entitled "Functional Properties of Soy Protein Concentrates and Functional, Nutritional and Sensory Properties of a Corn-Soy Concentrate Cereal as Influenced by Selected Calcium Salts." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Human Ecology.

Ada Marie Campbell, Major Professor

We have read this dissertation and recommend its acceptance:

Marjorie P. Penfield. Frances E. Andrews, David W. Brown

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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A. M. Campbell, Major Professor

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Vice Chancellor
Graduate Studies and Research

FUNCTIONAL PROPERTIES OF SOY PROTEIN CONCENTRATES AND FUNCTIONAL, NUTRITIONAL AND SENSORY PROPERTIES OF A CORN-SOY CONCENTRATE CEREAL AS INFLUENCED BY SELECTED CALCIUM SALTS

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ABSTRACT

The substitution of soy protein concentrates for soy flour in a USDA formulation for corn-soy blend and fortification with four calcium salts were investigated by functional, nutritional and preliminary sensory evaluations. A model system was used in an investigation of water absorption and Brookfield consistency of 4 soy concentrates, 2 powders and 2 grits, in the presence of calcium carbonate, calcium phosphate dibasic, calcium phosphate tribasic and calcium lactate, at levels of 0, 400, 800 and 1200 mg calcium/23.4 g concentrate and at ambient temperature (22-25°C) and 50°C. One powder and one grit concentrate were selected for use in a corn-soy cereal. Cereals representing all combinations of the 2 concentrates with the 4 calcium salts at levels of 0, 400, 800 and 1200 mg calcium/100 g cereal were evaluated at 50°C for water absorption and Brookfield consistency; the cereals also were evaluated for Bostwick and Brookfield consistency after cooking and cooling to 30°C. Cereals representing all combinations of the same concentrates and all 4 calcium salts at a calcium level of 540 mg/100 g diet were evaluated for nutritional quality by PER assay. One of the 2 concentrates, the powder, was tested in gruels containing all 4 calcium salts at a calcium level of 540 mg/100 g cereal. A panel of adults evaluated the gruel by the consumer texture profile technique and assessed the cereals' apparent acceptability when fed to infants.

The effects of soy concentrate were similar in the model system and the uncooked food system; grit concentrates and the uncooked cereal containing grit concentrate absorbed more water and had greater

suspension consistency than counterpart powder concentrates and cereal containing powder concentrate. However, in the cooked food system, the gruel containing powder concentrate was more viscous than the gruel containing the grit concentrate. The effect of temperature on both water absorption and Brookfield consistency in the model system was evidenced by greater values at 50°C than at ambient temperature.

Calcium salts had a significant effect on both water absorption and Brookfield consistency in the model system, whereas this effect was evident only for water absorption in the uncooked food system and for Brookfield consistency of the cooked gruel. Concentrates in the model system tended to absorb the most water in the presence of calcium carbonate and calcium phosphate tribasic and their suspensions were most viscous in the presence of calcium phosphate tribasic. Cereals containing calcium carbonate absorbed the most water and were the most viscous when cooked. Calcium lactate had the same effect in both systems; the least water was absorbed and suspensions were the least viscous in the presence of this salt. Both water absorption and suspension consistency tended to decrease with increasing level of calcium in the model system but calcium level did not affect the food system.

The numerous interactions observed in the model system indicate that the relationships among the variables studied are complex. Some possible effects of the variables and interactions in the food system possibly were masked by the presence of pregelatinized corn meal in the cereal.

Nutritional quality of the cereals was not affected by soy concentrate or by calcium salt. PER values for soy concentrate-calcium salt diet combinations ranged from 2.24 to 2.34 (based on 2.5 for casein). Sensory properties of the gruel were somewhat affected by calcium salt.

It was concluded on the basis of consistency and PER that either the grit or powder soy protein concentrates could be used to replace the less refined and processed soy flour in USDA's corn-soy blend. However, the calcium salt used for fortification needs to be selected with consideration of desired functional and sensory properties of the final product.

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CHAPTER I

INTRODUCTION

The use of plant proteins for human food requires consideration by food scientists of functionality—physical and organoleptic properties of the protein. Other factors that must be considered include nutrition—quantity and quality of the protein and the potential need for vitamins and minerals; physiology—no objectionable side effects (Horan, 1974); consumer acceptance of the finished food product; and the many factors for effective implementation of a new product into an economy (Austin, 1979). The soybean, one plant source, contains a high concentration of good quality protein; therefore, its use in human food will continue to be expanded. Soybeans are capable of producing a greater amount of protein per unit of land than any other major plant or animal source used as food by man (Meyer, 1968; Parman, 1974; Johnson, 1976). In addition soybean protein quality is such that it effectively complements cereal grains, the world's major calorie and protein sources. Advantage has been taken of this complementary relationship in the formulation of special mixtures of plant proteins for use in developing countries.

A formulation of soy flour (which contains 50% protein) and corn meal has received much attention for use in supplementary feeding programs for infants and children in developing countries (Crowley, 1975). The use of soy protein concentrate, a more refined, highly processed soy product of approximately 70% protein, in place of soy flour could result in a product that offers more protein per weight. To be a successful replacement, the soy concentrate must exhibit properties in the food product

similar to or better than those provided by the soy flour being replaced, while not being detrimental to the overall quality (Waggle and Kolar, 1979). A systematic determination of functional properties is essential to assess how a protein behaves in specific food systems and whether it can be substituted for other proteins (Kinsella, 1979). Water absorption and flow properties are two functional characteristics of importance to a corn-soy infant cereal. These characteristics can be affected by soy processing methods or environmental factors such as temperature, experimental conditions, particle size, ionic strength and added ingredients such as calcium salts. Often the functional properties are evaluated first in a model system to test predictability of performance of soy protein concentrates in the food system and to screen those proteins not exhibiting desirable functional characteristics for the food system under study.

Nutritional quality also is measured through rat studies using the protein efficiency ratio (PER) method. Results from such testing not only allow for evaluation of the quality of the protein or other nutrients within the formulated food but also provide information on the possible presence of adverse physiological factors (Bressani, 1969). The concern for protein "fortification" often overshadows the need for vitamin and mineral fortification, but these nutrients are important and should be considered. The form of mineral salt chosen for fortification needs to fit the product, causing no adverse physiological or functional effects (NRC, 1975). Calcium salts, in particular, are important mineral fortificants, especially if milk is not available. However, the addition of calcium salts in quantities great enough to achieve a desired calcium concentration may cause some technological problems.

If a nutritious formulated food is to be of any value, it needs to be consumed; thus it needs to be made available to and accepted by the consumer. Therefore, functional, nutritional and consumer evaluations of a formulated food are needed in order to determine the effect of replacing soy flour with soy concentrate and the effect of calcium. The following objectives of the study include these evaluations:

1. to evaluate water absorption and Brookfield consistency of soy protein concentrates, supplied in the grit and powder forms by two commercial sources, as unheated and heated slurries in a model system;
2. to study the effects of additions of four calcium salts (calcium carbonate, calcium phosphate dibasic and tribasic, and calcium lactate), each at four calcium levels, on water absorption and Brookfield consistency of the model system;
3. to evaluate, by both objective and sensory means, the functional performance of selected soy concentrates in a food system (infant cereal) as affected by the different calcium salts;
4. to investigate the PER value of selected cereal formulations.

CHAPTER II

REVIEW OF LITERATURE

Soy Proteins in Assistance Programs

The elimination of protein-calorie malnutrition has been and continues to be of primary concern the world over. Foreign donation programs, for which the USDA is responsible, have been established in the United States through several acts: an Act of Congress in 1949, Public Law (PL) 480 in 1954 and the Food for Peace Act in 1966 (Senti, 1969, 1974; Crowley, 1975). Over 75 billion pounds of food commodities were distributed under Title II of PL 480 during 1954-1973 (Crowley, 1975).

A corn-soy-milk (CSM) blend was one of the first mixtures formulated by USDA scientists in collaboration with nutritionists of the Agency for International Development (AID) and the National Institutes of Health (Tollefson, 1967; Bookwalter et al., 1968; Senti, 1972). CSM was developed within USDA guidelines for development and use of food commodities in overseas distribution (Senti, 1969, 1972). Since September 1966, CSM has been donated, with good acceptance, to more than 100 countries (Anderson et al., 1969; Graham et al., 1971; Liener, 1977). CSM is composed of 63% corn meal (pregelatinized to lessen cooking time), 23.7% soy flour, 5% nonfat dry milk, 5.5% refined soy oil and 2.8% vitamin and mineral premixes (USDA, 1975). This formulation was specifically developed for use as a dietary supplement for weaning infants and preschool children of low-protein status, and provides a minimum of 19% protein on a dry weight basis (d.w.b.) and two-thirds of the Recommended

Dietary Allowance (RDA) in a 100 g portion for a 1- or 2-yr-old child (Senti, 1972). The requirements for growth of these children put special demands on their diet compositions and their needs were not being adequately met by existing food programs (Bressani, 1969; Scrimshaw, 1969; Senti, 1969).

Other commodities have been developed and include a wheat-soy blend, a whey-soy drink mix and a corn-soy blend (CSB) (Crowley, 1975). CSB is a modification of CSM, intended for distribution to older children and other population groups. It is designed to contain a minimum of 16.7% protein (d.w.b.) (Senti, 1974) and presently is formulated with 71% pregelatinized corn meal, 22% soy flour, 5% refined soy oil and 2% vitamin and mineral premixes (USDA, 1978).

All of the above products contain soy in the form of flour, which has a protein content of approximately 50%. Soy protein concentrate, however, may be more feasible for incorporation into and supplementation of a broad variety of foods of various cultures, offering an improved color, a more acceptable flavor and the absence of certain flatulence-producing oligosaccharides (removed during processing) (Meyer, 1971; Johnson, 1976). Soy concentrate is produced from soy flour or grits, resulting in a product that is higher in protein and fiber but usually slightly lower in ash than soy flour. Since the concentrate contains not less than 70% protein (d.w.b.), a lower percentage may be used to get a desired protein level and possibly equivalent functional value as compared to that of soy flour (Johnson, 1970). However, if it is used in the same percentage, a higher protein content can be obtained (Johnson, 1976; Kinsella, 1979).

In the attempt to eliminate protein malnutrition, there is not only a need to improve formulation of accepted foods, but also a responsibility to evaluate the nutritional, functional and sensory qualities of these formulated foods as much as possible.

Nutritional Quality

If a soy product is to be accepted, it must be integrated into local food consumption patterns or blended with foods that may already be accepted, rather than presented as a separate new food item (Senti, 1969; Hutton, 1974; Liener, 1977). Tollefson (1967) reported that it is difficult to change the food habits of people who are close to starvation. Since more than 72% of the world population satisfies its caloric needs by consuming cereal diets in which wheat, rice and corn predominate (Scrimshaw, 1969; Buffa, 1971; Horan, 1974), these cereals would be good choices for use in blends with soy. Cereals have an obvious dietary significance in developing countries but, if unsupplemented, they are deficient in both protein quantity and quality. The prominence of cereal grain protein in diets causes concern as to their possible inadequacy for normal growth and development (Austin, 1979), especially since these cereals are almost universally made into gruels and fed to infants and preschool children in developing countries (Scrimshaw, 1969). These gruels are often an infant's first "solid" food and, as such, they should contribute bulk in a smooth, nonirritating form and the nutrients that an infant needs in the first few months of life (Harris and Von Loesecke, 1971). However, in unfortified cereal gruels, deficiency of protein relative to calories, combined with effects of infections, can result in clinical signs of an acute and often fatal protein deficiency disease,

kwashiorkor, found most often in young children no longer receiving sufficient protein from breast milk (Scrimshaw, 1969). Cereals, therefore, seem to be logical and perhaps needed products for "fortification" to meet the needs of many malnourished people of the world.

Soy serves as a good source of complementary protein for nutritional fortification of cereal grain foods because of the high content of lysine, the amino acid most often limiting in cereal grains (Wolf, 1970; Meyer, 1971). In particular, soy flour protein and corn meal protein (those used in CSM and CSB), have been shown to complement each other, yielding a mixture with a nutritive value higher than that of either component alone because of the more efficient mixture of amino acids (Bressani and Elias, 1966). Cheryan et al. (1979) reported that a minimum of 15% soybeans is needed in soy-corn mixtures to overcome lysine deficiency and a 22:78 ratio to overcome isoleucine deficiency. They found that a 33:67 soy-corn mixture exhibited the best protein quality, but only 20% soy could be added to cereals for organoleptic acceptance.

Biological testing. Nutritional quality of soy protein and soy-containing mixtures has been confirmed through biological testing with experimental animals and by feeding trials with humans. Although the validity of protein efficiency (PER) values has been questioned in the literature, PER is useful for indicating whether a protein is deficient in essential amino acids and for providing information on the possible presence of adverse physiological factors (Bressani, 1969). Soy protein concentrates have PER values comparable to those of soy flour, between 2.0 and 2.2 (based on 2.5 for casein, the reference protein). PER values for soy protein isolate (which is not less than 90% protein), however,

range from 1.0 to 1.9, indicating that the concentrate and flour may be nutritionally superior (Meyer, 1971; Rackis and Anderson, 1977).

CSM and CSB have PER values of 2.3-2.5 and 2.2-2.3, respectively (based on 2.5 for casein) (Senti, 1974), indicating that they are blends of good protein quality. Tested in feeding trials with infants and children, CSM has been found to support growth and nitrogen equilibrium (Graham et al., 1971; Graham and Baertl, 1974). Scrimshaw and Young (1979) also concluded from their study with adults that refined soy products are well tolerated and accepted by human subjects when consumed at significant intake levels over long periods of time.

Physiological factors. Soybeans are known to contain several antinutritional factors (Rackis, 1974; Anderson et al., 1979), of which trypsin inhibitors and phytates have been of most concern. Trypsin inhibitors have been shown to be destroyed satisfactorily with the heat treatment that occurs during soy processing, but reports of heat and processing effects on phytates have been contradictory. Phytates form complexes with a broad spectrum of minerals, which may affect the availability of minerals and produce a wide variety of deficiencies, depending on which element first becomes limiting under specified dietary conditions (Katz and Foulks, 1970; Liener, 1972; McBean and Speckman, 1974; Weisburg, 1974; Shelef and Morton, 1976; Martinez, 1977). Some authors contend that phytate content is reduced during processing (Liener, 1977; Bender, 1978). Reports of rat and human studies supported this statement, showing that phytate in soy protein foods did not interfere with mineral metabolism (Churella and Vivian, 1976; van Stratum and Rudrum, 1979). However, other researchers found soy concentrate and isolate reduced mineral availability

when compared to casein in rat feeding studies (Rackis and Anderson, 1977; Forbes et al., 1979). They suggested that the reduction may be attributable to the type of phytate-protein-mineral complexes formed during processing rather than phytate concentration in the soy. To overcome any possible mineral deficiencies because of the presence or formation of phytate complexes, several researchers suggested fortifying soy products with minerals (Liener, 1977; Rackis and Anderson, 1977).

Fortification

The importance of vitamins and minerals must not be overlooked in the development of highly nutritious and soy-containing foods (Horan, 1974). Foods selected for fortification should be those that are consumed rather consistently in order to obtain the desired effect (Harris, 1971; Kubler, 1973). Cereals would be an effective vehicle to carry fortification nutrients because of their universal consumption (Austin, 1978), as discussed earlier.

In general, fortification can provide a rapid, economical, flexible and socially acceptable method of improving the nutrient intake of a given population (Baurenfeind and Brooke, 1973). In addition, adding vitamins and minerals to formulated foods can increase nutritional quality without increasing the volume of food, which helps overcome the bulk constraint of children whose ingestion capacity is limited (Austin, 1978).

The objective in fortifying a food with any mineral is to add it in a biologically available form that does not react with any food component, cause any organoleptic problems or catalyze any undesirable reactions (Borenstein, 1971). The technological possibilities of enriching

foodstuffs are nearly unlimited, but application to products requires extensive examination in every case (Kubler, 1973), because there are many technological problems with fortification. These problems may include color, flavor, physical body, texture, cost and the biological value or availability of minerals after addition to a food product (NRC, 1975).

Of the possible minerals used in fortification, calcium could present the largest problems since large quantities of calcium salts (2.2-3.5 g) are required to meet the RDA (NRC, 1980) for calcium (540 mg for babies and 800 mg for adults), the guide most often used in the evaluation and setting of standards for nutritional quality (Senti et al., 1972). In addition, calcium excess may be desirable to improve the balance between calcium and phosphorus (Harris and Von Loesecke, 1971) and to overcome any possible binding by phytates or other dietary components (Harris, 1971). Large quantities of calcium salt could present problems in the form of chalky flavors, sandy mouth feel, opacity, sediment, color changes and difficult solubilization in foods (Borenstein, 1971; NRC, 1975). The extent to which these problems occur might also differ among calcium salts. NRC (1975) gives a list of 14 calcium salts suitable for addition to infant food in particular. Calcium salts with poor solubility in water, such as calcium carbonate and the calcium phosphates, are preferred by food technologists because they contribute little or no flavor to food and are the most stable (Harris, 1971). Calcium carbonate is the most widely used salt in cereal fortification (Austin, 1979), but its poor solubility suggests low bioavailability as compared with that of some other salts; in general biological availability parallels solubility

under conditions resembling those in the digestive system (Austin, 1979). On the other hand, Erdman (1979) found that calcium carbonate used in fortification of soy products was well utilized by rats. The more soluble salts, such as calcium lactate and calcium gluconate, show little promise in foods because of the reactivity of calcium ions with proteins, gums, emulsifiers, etc., as well as intensified flavor problems (Borenstein, 1971). The calcium phosphates have been suggested as the best compromise (Rubin and Cort, 1969; Borenstein, 1971; Harris, 1971; NRC, 1975). These salts are reported to have little effect on the pH of foods and to be preferred for their bland characteristics. They are almost insoluble in water but soluble in dilute acid. However, their use can present problems in maintaining an optimal calcium to phosphorus ratio, especially in a cereal blend. Therefore, the selection of a salt that is appropriate for the product is an important consideration when fortifying foods.

In addition to the minerals' chemical form, other dietary components may affect the bioavailability of the calcium salts. McBean and Speckman (1974) reviewed the interrelationship of calcium with other dietary components, including phosphorus, protein and phytic acid. The influence of dietary phytic acid in calcium metabolism is controversial. The presence of phytic acid in the diet may interfere with intestinal absorption of calcium, but some researchers indicate that the intestinal tract may contain a phytate-splitting enzyme; therefore, calcium-phytate binding would not reduce absorption (McBean and Speckman, 1974).

Functional Properties of Soy Concentrates

Sufficient information is available to formulate a food that contains required amounts of known nutrients, but formulation of products that will be accepted by the consumer is facilitated by the evaluation of the functional properties of food ingredients. Unless consumers are motivated by some medical or pseudo-medical reason, they will select foods that have desirable appearance, flavor and texture solely for the pleasure of eating and not for nutritional reasons (Johnson, 1970; Martinez, 1979).

Functional properties of proteins are defined by Kinsella (1976, 1979) as the intrinsic physicochemical characteristics that affect their behavior in food systems during processing, manufacturing, storage, preparation and consumption. These properties reflect the intrinsic physical attributes of protein per se (such as composition and structure), as affected by process treatments, interactions with other food components (water, ions, proteins) and immediate environment, such as temperature, ionic strength and pH (Johnson, 1970; Hermansson, 1979; Kinsella, 1979).

In evaluating or obtaining information necessary for the choice and handling of proteins as ingredients, systematic studies should be made to assess protein behavior (Hermansson, 1979; Kinsella, 1979). Hermansson suggested making the studies with simple model systems, combining several measurements; the pattern of information so obtained provides an early indication of the appropriateness of the functional properties for specific food applications. Such model systems can decrease the amount of large scale testing required, in addition to clearly identifying the functions of a protein ingredient. Considerable work has been reported

on functional properties of soy proteins in model systems (Hutton and Campbell, 1977a, b; Kinsella, 1979), since functional properties of a model system may also contribute to prediction of performance of the protein in a food system (Circle et al., 1964; Mattil, 1971; Hermansson, 1973; Onayemi and Lorenz, 1978). However, caution is needed in extrapolating findings from a model system to a complex food system. Hutton and Campbell (1977b) found that model and more complex systems sometimes differed in their response to variations in pH and temperature. It is difficult to reproduce the conditions—temperatures, mixing, multiple components, chemical and physical interactions, etc.—that may occur in the actual food system (Kinsella, 1979). Therefore, many researchers conclude that the final test of functionality of an ingredient that is to be used in a food system is to incorporate the ingredient in the particular food formulation (Johnson, 1970; Hermansson, 1973). Despite the limitations of model systems as predictors of possible food system effects, simple and rapid model systems can be used for screening of functional properties to provide information on compatibility of soy proteins with other components (Kinsella, 1976, 1979).

Wolf in 1970 and Wolf and Cowan in 1971 recognized the need for standard tests to measure functional properties that could be used to predict behavior of soy proteins in food products. In 1974, Mattil stated that there are no analytical tests that will characterize proteins adequately so that the potential users can determine which would be best for their purposes. More recently Kinsella (1976, 1979) considered the development of improved, standardized methods and techniques for measuring such properties still to be an urgent need. Solubility often

is used as a quick test of functional properties of soy proteins. However, solubility gives no information as to whether a protein ingredient will bind water or contribute to the texture of a product (Hermansson, 1979). Some systematic sequence of uniform testing to assess the influence of variable factors on protein functionality needs to be established (Kinsella, 1976). Unfortunately, this presently is done only in individual research studies to meet specific needs and goals. Product development still involves much trial and error because of the dearth of information concerning functionality as affected by other ingredients. Functional properties in model systems and performance in food systems need to be studied in relation to each other and as influenced by relevant variables.

Even though Martinez (1979) contends that nutritive quality is the primary functional characteristic affecting the use of soy flour in simple cereal-based mixtures, there are several functional characteristics important to the performance and acceptance of the product. Easy wettability, desirable viscosity (easy for infants to swallow but not so fluid that the protein and calories are diluted excessively), possible reaction or synergistic effects with other colloids to contribute to viscosity, controlled water absorption rates, and bland or compatible flavor are important for an infant cereal.

Functional Properties Selected for Study

Concentrates provide such functional characteristics as moisture absorption and they affect textural properties (Meyer, 1971), which can contribute to mouthfeel and, hence, to acceptability of a formulated product such as cereal. Both water absorption and flow properties, as

exhibited by soy concentrates, might reflect the composition and conformation of proteins, which in turn are affected by the processing conditions, the environment of the food system and the presence of non-protein components of the concentrate. It has been generally considered that the protein portion of soy protein-containing products is most responsible for the functional value. However, other constituents of soy flours and concentrates such as salts and polysaccharides can contribute to functionality (Johnson, 1970; Wolf, 1970; Martinez, 1979). Studies of water absorption and flow properties over a range of conditions (and concentrations) can be useful in assessing potential applications of new proteins (Kinsella, 1976).

Water absorption. Soy proteins contain numerous polar side chains along peptide backbones, making the proteins hydrophilic—capable of binding or absorbing water and retaining it in finished food products (Briskey, 1970; Wolf and Cowan, 1971). Hermansson (1979) reported that water binding of proteins may be caused by any of the following properties: the ability to swell and take up water, a high viscosity caused by soluble molecules and/or swollen particles and the ability to form a gel network during processing. In soy protein concentrates, the polysaccharides also absorb water and affect functional properties (Wolf and Cowan, 1971).

Various terms and descriptions of methods appear in the literature concerning protein hydration and its measurement. Water binding involves binding of water to ionic sites and hydrogen bonding between water and polar groups on the protein molecule, as well as between the tightly bound water and additional layers of water. Bound water is nonfreezable and may be measured by nuclear magnetic resonance (Hansen, 1978).

However, the term "water binding" frequently is used in a more inclusive sense in reference to water, both bound and trapped, that is held by the protein pellet after mild centrifugation of a protein dispersion (Kinsella, 1976). The term "water sorption" or "water adsorption" refers to moisture uptake by a dry sample during equilibration against water vapor at a known relative humidity (Kinsella, 1979) and may be determined as weight increase during equilibration. Kinsella (1979) described "water-holding" as the ability to "physically hold water against gravity." Investigators who have reported water holding capacity of soy proteins (Fleming et al., 1974; Lin et al., 1974) used a centrifugation method similar to that mentioned above for water-binding. Adding to the confusion in the literature is the interchangeable use of the terms "water absorption" and "water binding." Regardless of terminology applied to the method and the property measured, results may be expressed as percentage of sample weight, g water/g sample or g water/g protein.

Cheryan et al. (1979) measured water absorption of reconstituted 30:70 soy/corn mixtures and found that water was absorbed in an asymptotic manner before reaching a maximum, which they state is typical of equilibration processes of cereal products. Ziemba (1966) found that laboratory-prepared soy concentrates had 360-500% water absorption properties, compared with soy flour which had 350-380%. Values of 340-380% of dry weight of concentrates have been reported for those prepared by an alcohol leaching process (Wolf and Cowan, 1971). Water absorption values of 275-365% for Isopro concentrate (Fleming et al., 1974) and 196% for Promosoy-100 (Lin et al., 1974) have been reported.

Water absorption capacity varies with protein source, processing and composition of the protein product, presence of other ingredients such as

carbohydrates, lipids and salts and pH or other environmental conditions of the food system (Kinsella, 1976). Water absorption also is related to the viscosity of the system (Briskey, 1970; Kinsella, 1979). Hermansson (1975) reported good correlations between functional properties related to flow behavior and water-binding properties of added proteins.

Flow properties. Changes in hydrodynamic properties that occur when proteins absorb water and swell are often reflected in thickening and concurrent increases in viscosity (Hermansson, 1972; Kinsella, 1976). Viscosity changes and flow properties of protein dispersions are of practical interest because they can provide some information on suitable fields of application for a new product, are important for mouthfeel and hence acceptability of the food product and can be used for quality control and preparation of a final product (Levinson and Lemancik, 1974; Hermansson, 1975; Kinsella, 1979).

Soy protein in CSB may provide texture simply by thickening. This property can be measured crudely with the Bostwick consistometer or more accurately with the Brookfield viscometer. Bookwalter et al. (1968) used the Bostwick consistometer for evaluating properties of cooked CSM gruels and for quality control. A consistency value in the range of 10-20 cm/min after 1 min of cooking CSM at 11% concentration (as-is) was found to be satisfactory for feeding children. The viscometer, however, is a more sensitive instrument that can be used to evaluate the thickening power of soy proteins in dispersions. These dispersions are non-Newtonian in nature, demonstrating thixotropic behavior (Rao, 1977; Tung, 1978; Hermansson, 1979; Kinsella, 1979) and values frequently and appropriately are reported as apparent viscosity. Tung (1978) suggested that data

for non-Newtonian fluids obtained with the Brookfield Synchro-Lectric viscometer should be referred to as "Brookfield consistency."

Flow properties of protein dispersions are governed by composition, hydration and molecular shape, size and charge. Flow properties also may be influenced by environmental conditions of the food system, other food components and processing treatments insofar as they affect molecular conformation, structure, aggregation state, hydration and swelling (Tung, 1978; Kinsella, 1979). Rao (1977) divided factors influencing rheological properties of dispersions into those associated with the dispersed phase (volume concentration, particle size distribution, chemical constitution) and those associated with the continuous phase (viscosity, chemical composition, electrolyte concentration). Fleming et al. (1974) obtained a wide range of viscosities for soy proteins by varying temperature, mixing regime and slurry medium and by pH-activation. Information on these relationships may be used to modify rheological behavior or to select the product with the viscosity most suitable to the processing conditions, equipment and desired end product characteristics (Fleming et al., 1974; Tung, 1978).

Since both water absorption and flow properties are results of water-protein interactions and seem to be dependent on the balance between attractive and repulsive forces, the effects of processing and environment on these properties will be considered together.

Effect of Processing

The varying methods used for producing soy flour, concentrate and isolate result in products of different protein concentrations, as mentioned previously. Water absorption and viscosity have been shown to

increase with concentration of protein in the product (Fleming et al., 1974; Lin et al., 1974; Hermansson, 1975). Slurries of soy flours were somewhat lower than those of soy concentrates, which were somewhat lower than those of isolates in water absorption and viscosity. Kinsella (1979) suggested that the greater binding capacity of isolates over concentrates may be due to a greater ease with which isolate proteins swell, dissociate and unfold to expose additional binding sites, whereas carbohydrates and other components of the concentrate may impair water binding by protein.

Commercial preparation of soy concentrates may cause some denaturation of proteins and other physical and chemical changes; consequently, commercial concentrates differ in their functional properties. Concentrates are prepared from minimally heat-treated flours, but the type, extent and duration of additional treatments result in differences in functional properties. In addition, numerous other factors such as soy genotype and conditions of production, harvesting and storage may have an impact on functional behavior (Kinsella, 1976). Meyer (1971) reported that concentrates commercially produced by different processes may be similar in gross compositional characteristics but differ as to color, flavor, particle size and water and fat absorption. Viscosity is a property shown to be related to the denaturation process (Hermansson, 1978). Using some commercial soy isolates that were completely denatured, Hermansson found no viscosity increase on heating. Not only is it difficult to predict the effect of various processes on functional properties of proteins, but often the processing techniques used in commercial preparations are not made known to the consumer or researcher. Therefore, to study the effects of processing on soy

proteins, the soy would have to be processed in the laboratory under controlled conditions. Differences in properties of soy concentrates from different commercial sources can probably be attributed largely to processing variations.

Effect of Environmental Factors

Temperature. Temperature may positively affect water absorption and viscosity of soy dispersions. Water absorption of a soy protein concentrate and an isolate tended to increase as temperature increased from ambient to 90°C (Hutton and Campbell, 1977a). Heated soy isolate dispersions at a given concentration also exhibited greater viscosity than unheated dispersions (Circle et al., 1964). Dispersions of concentrate, Promosoy-100, had higher apparent viscosity at 90°C than at either ambient temperature or 4°C (Hutton and Campbell, 1977b). Wolf and Cowan (1971) suggested that during the conversion from sol to progel, viscosity increases as the temperature is raised until a maximum is reached. At higher temperatures, viscosity decreases as a result of irreversible conversion to a metasol state that does not gel on cooling.

Other experimental conditions. Variations in experimental conditions for determining water absorption and flow properties such as mixing time of slurry and sample concentration will result in different values for the same soy protein product. Water absorption was generally lower and viscosity higher in soy slurries subjected to a long rather than a short mixing period (Fleming et al., 1974). Viscosity of soy protein dispersions often increases exponentially with increasing concentration of each soy product (Fleming et al., 1974; Tung, 1978). However, the

viscosity of the soy concentrate Isopro was similar to that of flour at low concentrations but more than tenfold greater in a 20% slurry (Fleming et al., 1974). In extremely dilute dispersions, the total viscosity effect is the sum of the effects of the individual suspended particles (Tung, 1978). However, as concentration increases, the disturbances of solvent flow produced by suspended particles are no longer independent because flow patterns overlap, and aggregation and solvent immobilization occur.

Particle size. Concentrates are available in a variety of mesh sizes for various food uses (Ziemba, 1966). Particle size and distribution may influence total absorption, rate of water absorption, rate of development of viscosity, final viscosity and mouth feel of the final product (Johnson, 1970). Fine particles have a tendency to absorb liquids more rapidly than coarser particles (Johnson, 1970; Wolf and Cowan, 1971). In addition, the presence of fine materials will give the final product a more pasty appearance rather than a chunk-like one.

Ionic strength. Salts may affect electrostatic interactions that might play an important role in the structure of soy proteins, especially in aqueous systems (Wolf and Cowan, 1971). When ionic strength is changed, the proteins undergo association-dissociation reactions. Water absorption of 15% soy-water slurries decreased more for soy isolates than concentrates and increased for soy flours when the slurries contained 5% NaCl (Fleming et al., 1974). Fleming et al. also found viscosity to increase for both soy concentrates and soy flours when NaCl was added. However, soy isolate slurries have been shown to decrease in

viscosity with the addition of NaCl (Hermansson, 1975; Kinsella, 1979). Hermansson explained that the change is caused by the presence of less swollen, more rigid aggregates and less solvated protein molecules.

Calcium salts. Calcium has been reported to precipitate preferentially the 11S protein fraction of soy and it is the behavior of the 7S and 11S globulins that determines the functional properties of both soy concentrate and soy isolate (Kinsella, 1979). Most mineral salts used in nutrient fortification of new foods are added in such small quantities as to have little effect on functional properties of a system. Calcium salts, however, are often added in large enough quantities to affect a system. In addition, calcium is a known coagulant of soy protein and, therefore, is used as a curding agent in soybean curd production (Wolf and Cowan, 1971; Lee and Rha, 1977). This action could cause instability of a soy protein suspension. Therefore, soy protein-calcium complexes need to be regulated and stable in suspension-type food systems if it is desirable to maintain a uniform fluid phase (Lee and Rha, 1977). Lee and Rha found that calcium (as $CaCl_2$) caused an increase in apparent viscosity of soy protein isolate suspensions (1-7% protein concentration). Heating of protein dispersions to 70-80°C prior to addition of calcium accentuated this apparent viscosity effect.

Calcium also has been found to affect the color of products. NRC (1975) reported that insoluble calcium salts produce a lighter color than would otherwise result in sterile liquid dietary products and that soluble salts used at the high levels found in special dietary products cause products with a darker color than would normally exist. The addition of calcium (as $CaCl_2$) to soy suspensions changed the color from

green-yellow to white with an increase in sheen (Lee and Rha, 1977). Most of the effects and possible technological problems of fortifying foods with calcium or other mineral salts are not discussed in the literature, because industry has had to solve them during the development of various food products (NRC, 1975).

CHAPTER III

PROCEDURES

Source of Soy and Calcium

Soy Protein Concentrates

Four soy protein concentrates, two powder and two grit forms, were obtained from their commercial sources as identified in Table 1.

Table 1--Identification of soy protein concentrates by commercial sources and their descriptions

Concentrate	Commercial Source	Description
Promosoy-100	Central Soya (1978)	Free flowing powder with a particle size such that 95% of the product passes a 100 mesh screen
Promosoy 20/60	Central Soya (1978)	Granular product
Ardex 700F	Archer Daniels Midland Co. (ADM, 1978)	Free flowing flour with a particle size such that 95% of the product passes a 100 mesh screen
Ardex 700G	Archer Daniels Midland Co. (ADM, 1978)	Grit form consisting of irregularly shaped particles of such size that all passes through a 20 mesh screen and at least 98% is retained on an 80 mesh screen

Composition of the concentrates as reported in the technical data sheets is shown in Table 2. Both suppliers produce concentrates with protein contents, on a moisture free basis, of not less than 70%. In addition to the characteristics indicated,

Table 2--PER[a] and composition[b] of the soy protein concentrates

	Promosoy-100	Promosoy 20/60	Ardex 700F and G
PER (casein = 2.5)	2.29	2.29	2.00
	----------------	% ----------------	
Moisture	5.5	8.7	8.0
Fat	0.5	0.5	1.5
Protein, N x 6.25 (as-is)	66.6	65.4	65.3
Protein, N x 6.25 (moisture-free basis)	70.5	71.7	71.0
Crude fiber	3.5	3.5	3.7
Ash	6.2	6.2	4.5
Calcium	0.255	0.255	0.365

[a]Protein efficiency ratio = g wt gain/g protein intake.

[b]Composition provided by the commercial sources (Central Soya, 1978; ADM, 1978).

> Promosoy can be used in applications similar to those in which soy flour and grits are used. Because of its bland flavor and light color, Promosoy may be used at higher levels. Since Promosoy has a low sodium content (0.005%), a good nutritional profile, and is practically free of the flatulent-including carbohydrates, it can be used to an advantage in some specialty diet food systems (Central Soya, 1978).

ADM (1978) indicates that its Ardex 700 products have a low flavor profile and a high degree of functionality and thus are suited to a wide range of potential applications including baby foods, cereals, dry mixes and milk replacers.

Sufficient quantities (25-, 35- or 50-lb bags) of the soy protein concentrates were secured from the suppliers so that all samples of each

product were from the same lot. These were stored in large plastic bags within covered plastic storage bins. Kjeldahl nitrogen analysis (AOAC, 1975) and moisture determination (AOAC, 1975) were conducted on the samples, the latter being conducted initially and repeated at frequent intervals throughout the study. Results of these determinations are shown in Table 3.

Table 3. Moisture and Kjeldahl determinations on soy protein concentrates

	Promosoy		Ardex	
	100	20/60	700F	700G
	--------------------	%	--------------------	
Moisture[a]	5.73±0.12	7.72±0.08	5.70±0.6	8.84±0.08
Protein, N x 6.25 (as-is)	79.8±0.5	79.5±0.7	70.2±0.1	69.9±0.4
Protein, N x 6.25 (moisture-free basis)[b]	84.6±0.6	86.2±0.7	74.4±0.1	76.7±0.5

[a]2 g sample, dried 1 hr in air oven at 130±3°C (AOAC, 1975).

[b]Calculated value.

Calcium Salts

Four calcium salts were obtained from Mallinckrodt, St. Louis, MO (Table 4). The levels of calcium chosen for this study were based on those recommended or previously used for infants, as shown in Table 5. A reference point of 600 mg/100 g cereal was selected. This level would supply all the calcium needed for growth and maintenance (100% U.S. RDA) of an infant if 100 g cereal per day were consumed without the addition of milk. Therefore, calcium levels for study were set at 0, 400, 800 and 1200 mg/100 g cereal.

Table 4--Identification of calcium salts (Mallinckrodt, 1979)

Calcium Salt	Formula Weight	Calcium %	Grade[a]	Cost $/lb[b]
Calcium carbonate ($CaCO_3$)	100.09	40.04	USP	5.50
Calcium phosphate dibasic ($CaHPO_4 2H_2O$)	172.10	23.29	NF	8.68
Calcium phosphate tribasic ($Ca_3(PO_4)_2$)	310.20	38.76[c]	NF	37.40
Calcium lactate ($C_6H_{10}CaO_6 . xH_2O$)[d]	308.30	13.00	USP	10.28

[a]Grades: USP - United States Pharmacopoeia; NF - National Formulary, both grades for prescription compounding.

[b]Costs based on April 1979 prices.

[c]The salt as listed by Fisher Scientific had a slightly different formula weight and percentage calcium (39.89) from that of $Ca_3(PO_4)_2$, which was actually used. The calculations of amounts of salts to be used were inadvertently based on 39.89% calcium rather than 38.76%. Therefore the calcium level in all samples containing $Ca_3(PO_4)_2$ was slightly lower than indicated hereafter (actually 389, 778 and 1166 rather than 400, 800 and 1200 mg respectively).

[d]Salt formula contains 5 molecules of water as obtained by moisture determination (AOAC, 1975).

Table 5--Levels of calcium and types of calcium salts recommended and/or used for infants and/or babies in infant foods

Source	Age	Calcium (mg)
RDA (NRC, 1980)	infant[a] baby	360/day 540/day
FAO/WHO (1962)	0-12 mo (not breast fed)	500-600/day
U.S. RDA (NRC, 1975)	infant	600/day
Graham et al. (1969)[b] $CaHPO_4$	infant[c] baby	414/day 623/day
Irwin and Kienholze (1973)	0-12 mo	40-120/kg body wt
AID's CSB[b] (USDA, 1978) calcium carbonate calcium phosphate dibasic	----[d]	380/100 g cereal
Gerber's High Protein Cereal calcium carbonate-phosphate	----[d]	634/100 g cereal[e]

[a]Infant is considered to be 0-0.5 yr of age and weigh 6 kg; baby is considered to be 0.5-1 yr of age and weigh 9 kg.

[b]Mixtures also contain calcium pantothenate, but the calcium quantity is so low that it need not be considered.

[c]Graham et al. fed 1 g of mixture/day/kg of body wt.

[d]Not given.

[e]Based on serving size, 14.2 g, which supplies 15% U.S. RDA of calcium for infants (Gerber Products Co., Freemont, MI).

Because of the nutritional significance of calcium and the variability of calcium concentration in different salts, the selected calcium salts were used on an equal-calcium basis at each of the four levels rather than on an equal-salt weight basis (with the exception of calcium phosphate tribasic as explained in Table 4, footnote c).

Table 6 indicates the amount of each of the salts used at each of the 4 levels per 23.4 g soy concentrate, the amount that was to be contained in 100 g cereal. The amounts of the salts are presented also in g/g soy concentrate. The salt:soy ratios were constant for the different measurements made in the model system.

Table 6--Amounts[a] of each calcium salt in 100 g cereal containing 23.4 g of soy concentrate

Calcium Salt		Calcium levels (mg)			
		0	400	800	1200
Calcium carbonate	g/100 g cereal	0	0.9990	1.9980	2.9970
	g/g soy	0	0.0427	0.0854	0.1281
Calcium phosphate dibasic	g/100 g cereal	0	1.7170	3.4350	5.1520
	g/g soy	0	0.0734	0.1468	0.2202
Calcium phosphate tribasic	g/100 g cereal	0	1.0030	2.0060	3.0080
	g/g soy	0	0.0428	0.0857	0.1286
Calcium lactate	g/100 g cereal	0	3.0770	6.1540	9.2310
	g/g soy	0	0.1315	0.2630	0.3945

[a]Amounts calculated according to the following formula: designated Ca level, g/(0.01 x % Ca in salt).

Model System

Plan of Study

Water absorption and flow properties of the four soy protein concentrates as affected by the addition of the four calcium salts at the four calcium levels, as described previously, were studied in a model system. These soy concentrate-calcium salt-calcium level combinations were studied at ambient temperature and 50°C, at the as-is pH.

Water absorption and Brookfield consistency were studied with a 4 x 2 x 4 x 4 factorial plan that included 4 types of soy protein concentrate, 2 temperatures, 4 calcium salts and 4 levels of calcium with 2 replications. Data were collected according to a split-plot design in which there was a whole-plot effect of soy concentrate-temperature and their interactions and a split-plot effect of calcium salt-calcium level combinations and their interactions with the whole plot. Since it was most efficient to test 8 samples at a time and it was desired to study the effects of type and level of calcium salt with greater sensitivity than the effects of soy class and temperature, the 16 calcium salt-calcium level combinations were divided into 2 blocks. Each block of eight combinations consisted of two calcium salt-calcium levels of each of the four salts as shown in Table 7. In each block the soy type and temperature were constant. The 32 combinations of 4 soy concentrates, 2 temperatures, 2 blocks of calcium salt-calcium level combinations and 2 replications, were randomized as were the combinations within each block (Table A-1, Appendix A). Water absorption and Brookfield consistency data collection plans were randomized separately.

Table 7--Split-plot arrangement of calcium salt-calcium level combinations used for data collection of model and food systems

Salt	Block 1	Block 2
	--------- mg calcium --------	
Calcium carbonate	0, 800	400, 1200
Calcium phosphate dibasic	0, 800	400, 1200
Calcium phosphate tribasic	400, 1200	0, 800
Calcium lactate	400, 1200	0, 800

The effects of type of soy, temperature, type of calcium salt, level of calcium and all interactions were estimated by analysis of variance for water absorption and Brookfield consistency. Sums of squares for the main effects and interactions were partitioned by the use of polynomial equations. From the polynomials, the estimated curves for both measurements were drawn with a Hewlett-Packard flatbed plotter.

Consistency was proposed to be studied also with the use of a Bostwick consistometer. However, preliminary work indicated that the slurries of the various soys differed so much in consistency, that it was not possible to measure consistency at a single concentration. Therefore, this measurement was not made for the model system.

Measurements

Water absorption. Water absorption of the model system was determined according to a modification of Sosulski's (1962) method. Modification in part consisted of the determination of total solids in the supernatant (FSNFSA, 1976).

Eight determinations were carried out simultaneously. Five g of soy concentrate were weighed to the nearest 0.1 mg into each of 8 labeled and preweighed weighing bottles. If not immediately used, the filled bottles were covered and stored in a desiccator. Each sample was transferred, along with the appropriate calcium salt, to a labeled and preweighed 50-ml centrifuge tube. The levels of calcium salts were five times the amounts given in Table 6 for g/g soy since 5 g of soy were used. Each empty weighing bottle was reclosed and reweighed (later) to get actual weight of sample transferred (actual sample weight = weighing bottle with sample - weighing bottle with sample removed).

Thirty ml of distilled water were added by buret to each sample, while washing down the inside of the centrifuge tube. A "bent" (⌇) glass stirring rod was attached to a Talboys No. 124 electric stirrer and each sample was stirred for 1 min at rheostat setting 25. Each suspension was allowed to rest 10 min in a water bath at the predetermined temperature of ambient or 50°C. During this time, any suspension adhering to the side of the centrifuge tube was scrubbed down with the glass rod to prevent it from drying. Each suspension was stirred 7 additional times for 20-sec periods, with 10-min rest periods in the water bath following each stirring. Ten ml of distilled water were used to wash traces of sample adhering to each stirring rod into the corresponding centrifuge tube. The suspensions were centrifuged at 1570 x G in an International Model U Centrifuge, for 25 min. Each supernatant was decanted into a 7.5-cm diameter flat-bottomed aluminum dish that had been dried in an air oven at 105-110°C for 30 min, cooled in a desiccator for 20 min and weighed to the nearest 0.1 mg. The aluminum dishes containing the supernatants were placed on a steam bath for approximately 1 hr to evaporate the visible liquid. The outside of each dish was wiped off and the dishes were placed in an air oven set at 100-105°C, for 10 min. The dishes were cooled in a desiccator and weighed to the nearest 0.1 mg. While the supernatant liquid was being evaporated, each centrifuge tube with residue, was placed mouth down on paper toweling at an angle of 15-20° in an air oven at 50°C and allowed to drain and dry for 25 min. The samples were cooled in a desiccator for 1 hr and weighed to the nearest 0.1 mg to attain the hydrated weight. The water absorption was calculated according to the following equation: water absorption, % = $100 \times \frac{A - B}{B}$, where A = hydrated sample weight and B = actual sample

weight (original weight of concentrate + weight of calcium salt, if added - weight of total solids lost in supernatant).

Brookfield consistency. Brookfield consistency was measured on the model system according to a procedure developed in preliminary work. Slurry percentage, spindle size and speed and rotation stabilization time were determined so that one quantity of soy could be used for all four soys and so that all readings would be on-scale. The procedure described below was thus developed.

Eight determinations were carried out with 14-min intervals of initiation. For each determination the appropriate calcium salt at the appropriate level (75 times the amounts given in Table 6 for g/g soy) was dissolved in 425 ml of distilled water contained in a 600-ml beaker. Each suspension (approximately 15%) was prepared by adding 75.0 g of soy concentrate to the calcium salt dispersion at ambient temperature while stirring with a spatula having a 10.2 cm long x 1.7 cm wide stainless steel blade. Each suspension was stirred gently for 3 min with the spatula to smooth any lumps that formed and allowed to rest 30 min in a water bath at the predetermined temperature of ambient or 50°C. The suspension was stirred for 30 sec with the spatula and transferred into three 250-ml tall Griffin beakers to an equal depth; the 3 subsamples were placed in the water bath for 15 min for temperature equilibration.

The consistency was measured with a Brookfield LVF model viscometer with spindle 2 at 30 rpm. If the 50°C temperature was being used, each sample was placed in a 50°C sand bath while stirring and reading were taking place. The sample was stirred for 20 sec and the viscometer was lowered into the sample to the indentation on the spindle. The viscometer

was turned on and the spindle was allowed to rotate once with the clutch depressed; the clutch was released and the reading recorded after 1.5 min. The other two subsamples were measured likewise and all three measurements were repeated, resulting in a total of six readings per sample. The readings were averaged and adjusted to centipoise units by multiplying by 10, the appropriate conversion factor.

Food System

Plan of Study

A modification of USDA's (1978) CSB, both as a dry cereal and mixed with water to form a gruel, was used as the food system to further study water absorption, dispersion flow properties and protein quality of the soy protein concentrates. Powder and grit concentrates (Ardex 700F and G) were chosen for the evaluation of functional and nutritional properties in the food system. Selection was made on the basis of better physical appearance and less variation in water absorption and consistency between powder and grit forms from the same supplier.

All 16 calcium salt-calcium level combinations used in the model system also were used for evaluation of functional properties of the food system. The amounts of calcium salts used in 100 g of cereal are shown in Table 6, page 29. The salt:soy ratios differed very slightly from those used in the model system; the calculations for the model system were based on the plan to use 23.4 g of soy concentrate/100 g cereal for the food system (based on USDA's formula for corn-soy-milk), whereas the actual amount of soy concentrate used in the food system was 22.0 g/100 g cereal (based on USDA's formula for CSB).

Sufficient quantities of the cereal without calcium salts were prepared so that all samples for each measurement were from the same batch. Water absorption and dispersion flow properties, including Brookfield and Bostwick consistency, of the cereals were studied with a 2 x 4 x 4 factorial plan that included 2 types of soy protein concentrate, 4 calcium salts and 4 levels of calcium with 2 replications. Data collection and analyses for the food system objective measurements were similar to those used in the model system except eight combinations of two soy concentrates, two blocks of calcium salt-calcium level combinations and two replications, were used and temperature was not a variable.

The effects of the independent variables and all interactions were estimated by analysis of variance for all objective measurements. Sums of squares for the main effects and interactions were partitioned by the use of polynomial equations. From the polynomials, the estimated curves for all measurements were drawn with a Hewlett-Packard flatbed plotter.

Measurement of flow property with the Brabender amylograph also was proposed. However, preliminary work indicated that the gruel with or without selected calcium salts did not produce a curve.

Both cereals containing all 4 calcium salts at a calcium level of 540 mg/100 g diet were evaluated for nutritional quality by the protein efficiency ratio (PER), which involves using a casein diet as the control. PER assays were determined with groups of 10 rats arranged in a randomized complete block design by weight so that all initial group weights were 50.0 ± 0.8 g/rat. Analysis of variance was used to partition any variation attributable to soy type, calcium salt and their interaction.

A powder concentrate (Ardex 700F) was used in a limited sensory evaluation. Selection of a powder was based on its physical similarity to the flour used in the USDA's corn-soy blend. Gruels containing the concentrate and the 4 calcium salts at a calcium level of 540 mg/100 g cereal were evaluated for texture characteristics by adults, who also assessed the gruels' apparent acceptability when fed to infants. This portion of the research was a preliminary investigation involving three adult-infant pairs only; therefore, no tests of significance were applied. However, adult texture scores on the various texture parameters were averaged and plotted against their texture scores for an ideal infant gruel to consider possible trends. A larger consumer population of adults and infants will be used in an evaluation of these gruels in a follow-up study.

Measurements

Preparation. For the objective and sensory measurements, cereal was prepared according to a modification of the formula and ingredient specifications given by USDA (1978), as shown in Table 8. Soy concentrate was substituted for soy flour on an equal percentage basis and the type and level of calcium salt were varied. Total amounts of cereal needed for all measurements were determined and two separate batches were prepared; in one the soy used was a powder (Ardex 700F) and in the other a grit (Ardex 700G). All the ingredients listed in Table 8, except oil and the calcium salts, were combined and dry-mixed 30 min at speed 1 with the paddle attachment on a Hobart mixer, model D-300T. The oil was added all at once and the mixture was blended an additional 30 min. From each of

Table 8--Ingredient proportions and quantities prepared for each cereal without calcium salt[a]

Ingredient	Percentage	Quantity Prepared
	--- % ----	-- g ---
Corn meal processed (pregelatinized)[b]	71	2840.0
Soy concentrate (Ardex 700F or G)	22	880.0
Soy oil[c]	5	200.0
Vitamin antioxidant premix[d]	0.1	4.0
Mineral mix[e]		
Zinc sulfate, hydrated USP TAC ($ZnSO_4 . 7H_2O$)	0.004	0.16
Ferrous fumarate USP TAC ($FeC_4H_2O_4$)	0.046	1.84
Iodized table salt	0.650	26.0

[a]Calcium salt was added individually to samples before measurement.

[b]Corn meal composition. Supplier's specifications: 12% moisture, 11% protein, 2% fat, 2.5% fiber, 1.25% ash (Krause Milling Co., Milwaukee, WI); investigator's analyses: 9.6% moisture (AOAC no. 13.004) and 10.0% protein (AOAC, 1975).

[c]Crisco oil, partially hydrogenated soybean oil (Procter & Gamble, Cincinnati, OH).

[d]AID Premix 1010 composition (g/2 lbs): thiamine mononitrate 2.5, riboflavin 3.5, pyridoxine HCl 1.5, niacin 45.0, d-calcium pantothenate 25.0, folacin 1.8, vitamin B_{12} 0.036, vitamin A (stabilized retinyl palmitate) 60.0 = 15.0 MM Units, vitamin D_2 18.0 = 1.8 MM Units, dl-alpha tocopheryl acetate 136.0 = 68,000 IU vitamin E, butylated hydroxy anisole 20.0, butylated hydroxy toluene 20.0, ascorbic acid 364.0, corn starch q.s. (Hoffmann-La Roche, Inc., Nutley, NJ).

[e]Individual mineral salts were finely ground in a ball mill before use, and each was weighed and added separately to the cereals. Zinc and iron salts were obtained from Mallinckrodt, St. Louis, MO.

the two blended cereals, 5.0 g were used for each water absorption measurement, 75.0 g for each uncooked Brookfield consistency measurement and 23.5 g for each cooked Bostwick and Brookfield consistency measurement. The amounts of the 4 calcium salts in the individual samples were calculated on the basis of the amounts in 100 g cereal (Table 6, page 29). The cereals were stored in covered plastic containers in the refrigerator before use.

Water absorption. Water absorption of the 2 cereals was determined at 50°C according to the procedure used in the model system, except 5.0-g samples of cereal were used and the amounts of calcium salts were 20% of the amounts given in Table 6 for g/100 g cereal.

Brookfield consistency of uncooked cereal suspensions. Brookfield consistency of the 2 uncooked cereal suspensions was determined at 50°C according to the procedure used for the model system, except 75.0-g samples of cereal were used and the amounts of calcium salts were 75% of the amounts given in Table 6 for g/100 g cereal.

Bostwick and Brookfield consistency of cooked gruel. Bostwick and Brookfield consistencies of the 2 gruels were determined on the same samples at 30°C, after cooking, according to a modification of Bookwalter et al.'s (1968) method.

Eight determinations were carried out with 10-min intervals of initiation. For each determination the appropriate calcium salt at the appropriate level (23.5% of the amounts given in Table 6, page 29, for g/100 g cereal) was dissolved in 157.2 g of distilled water contained in a preweighed 600-ml beaker. The beaker was covered with foil and the

contents were brought to a boil on an electric burner ($\geq$ 315°C) covered with an asbestos mat. Each suspension (approximately 13%) was prepared by gradually adding 23.5 g of cereal to the liquid while stirring vigorously with a spatula. The suspension was brought back to boiling and boiled for 2 min with vigorous stirring. The beaker was removed from the burner, and the suspension was stirred for 30 sec; the beaker was covered with foil and placed in a water bath at 30°C for 10 min. The beaker was placed on a top-loading balance, the foil was removed and water was added until the slurry weight was 180.7 g. The slurry was stirred 15 sec with the spatula, recovered with foil and placed in the water bath at 30°C for 1 hr.

For measurement of Brookfield consistency each beaker was removed from the water bath, and the slurry was stirred 15 sec with the spatula and poured into a 250-ml tall Griffin beaker. A Brookfield LVF model viscometer with spindle 3 was lowered into the sample to the indentation on the spindle. The viscometer was turned on, the spindle was allowed to rotate at 30 rpm once while the clutch was depressed; the clutch was released and the reading was recorded after 1 min. The reading was adjusted to centipoise units by multiplying by 40, the appropriate conversion factor.

The slurry was restirred for 15 sec and poured into the reservoir of the Bostwick consistometer; the excess was removed with the straight edge of the spatula. The slurry was allowed to rest for 30 sec, the release lever was tripped and the distance of flow was read after 1 min (readings at the two sides and the center of slurry flow were averaged).

To equilibrate the temperature of the Bostwick consistometer, it was placed in the 30°C water bath for 5 min after cleaning, dried and placed at room temperature for at least 1 min before adding the slurry.

Nutritional evaluation. The standard AOAC (1975) procedure for conducting protein efficiency ratio (PER) assays was used for comparing protein quality of eight experimental diets having all combinations of the two cereals and the four calcium salts at one selected calcium level. A control diet contained casein (ICN Vitamin Free Casein, Nutrition Biochemicals, Cleveland, OH) as a reference protein.

Male weanling Sprague-Dawley rats (Harlan Industries, Inc., Indianapolis, IN) were acclimated for 4 da during which they were fed the control diet. From this group, 90 rats with initial body weights of 42.0-57.0 g were selected. These were blocked into groups of 10 rats for the 9 dietary treatments so that the body weights for the groups averaged 50.1-50.5 g/rat. The animals were housed individually in stainless steel wire bottom hanging cages and weighed at weekly intervals for a period of 28 days. Diets and water were supplied ad libitum.

The diets contained 10% protein based on Kjeldahl nitrogen analysis (AOAC, 1975). Diets also were adjusted so that all experimental diets and the control diet had the same content of moisture (AOAC, 1975), and of fat, ash and crude fiber (based on suppliers' analyses of casein, soy products and corn meal). The analytical values on which the calculations were based are in Table A-2 (Appendix A). The composition of the nine diets, as shown in Table 9, differed only with respect to the type of calcium salt used in the mineral mix and whether the cereal diets contained the soy powder (Ardex 700F) or the soy grit (Ardex 700G). The

Table 9--Composition of diet mixtures used for PER assays (g/100 g diet) with variations in protein source and calcium salt[a]

Ingredients	Casein	Corn-Ardex 700F				Corn-Ardex 700G			
	CO_3	CO_3	P_2	P_3	L	CO_3	P_2	P_3	L
Casein	10.73	-	-	-	-	-	-	-	-
Ardex 700F	-	9.21	9.21	9.21	9.21	-	-	-	-
Ardex	-	-	-	-	-	9.44	9.44	9.44	9.44
Corn meal	-	29.71	29.71	29.71	29.71	30.47	30.47	30.47	30.47
Salt mixture[b]	3.68	3.68	4.65	3.68	6.48	3.68	4.65	3.68	6.48
Soybean Oil	8.00	7.27	7.27	7.27	7.27	7.25	7.25	7.25	7.25
Vitamin mixture[c]	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235
Cellulose (alphacel)	1.00	-	-	-	-	-	-	-	-
Sucrose	38.18	24.95	24.47	24.95	23.55	24.46	23.98	24.46	23.06
Cornstarch	38.18	24.95	24.47	24.95	23.55	24.46	23.98	24.46	23.06

[a]Calcium salt: CO_3 - calcium carbonate; P_2 - calcium phosphate dibasic; P_3 - calcium phosphate tribasic; L - calcium lactate.

[b]Each mixture contained the following (g): NaCl 0.1303, $MgSO_4.7H_2O$ 0.4057, KH_2PO_4 1.7575, KI 0.00002, $CuSO_4.5H_2O$ 0.00196, NaF 0.00022, $FeC_4H_2O_4$ 0.0106, $MnSO_4.H_2O$ 0.0154, $ZnSO_4.7H_2O$ 0.0053, plus one of the following calcium salts: CO_3 - 1.349, P_2 - 2.318, P_3 - 1.354 or L - 4.154.

[c]Vitamin mixture contained the following (mg): vitamin antioxidant premix 100.0 (see Table 8 for composition), Vitamin K_1 (2 methyl naphthoquinone) 0.5, choline chloride 134.03, pyridoxine HCl 0.565.

vitamin and mineral mixtures were prepared and added to meet NRC (1978) laboratory rat requirements; these compositions are given in Table 9. Each mineral mix was blended in a ball mill before addition to the individual diets. All diet ingredients were combined and blended in a Hobart mixer model C-100 with a paddle attachment and stored in the refrigerator before use.

The calcium level used in the PER study was based on a human baby's RDA, 540 mg calcium/day (NRC, 1980). This calcium quantity differs slightly from the U.S. RDA of 600 mg calcium/day, on which were based the selected calcium levels used in the model and food systems. The fortification level of 540 mg calcium/100 g diet used in this study is equivalent to 81 mg calcium in 15 g diet, the approximate amount that a rat consumes daily. This calcium level, 0.54% of the diet, is comparable to the NRC (1978) rat requirement, 0.50%. The actual quantities of calcium salts used are given in Table 9.

Protein efficiency ratio (g wt gain/g protein intake) was calculated weekly for each group and averaged to give overall PER. The casein control diet was included as a reference protein to allow calculations of adjusted PER in which protein quality of an experimental diet is reported as 100 x ratio of experimental diet PER to casein PER.

Kjeldahl analysis was used to determine the protein content of the cereals to establish whether USDA's (1978) minimum protein requirement for CSB, 16.7% (N x 6.25), was being met and to compare the protein content of the corn-soy concentrate cereals with those reported for CSB (which contains soy flour).

Sensory evaluation. The cereal containing the powder concentrate, Ardex 700F (Table 8, p. 37), was mixed separately with each of the 4 calcium salts at a level of 540 mg of calcium/100 g cereal (based on an infant's RDA). To achieve this calcium level, the calcium salts were added in the following amounts (g/100 g cereal): calcium carbonate - 1.349 g; calcium phosphate dibasic - 2.318 g; calcium phosphate tribasic - 1.354 g; and calcium lactate - 4.154 g. The cereal and calcium salt were dry mixed with the paddle attachment on a Hobart mixer, model N-50, until well blended. Individual servings of the product were weighed (15.0 g) and placed in Ziploc sandwich bags (The Dow Chemical Co., Indianapolis, IN) and stored in the refrigerator until used. For the adult evaluation, 1/4 cup of boiling water was placed in a white bowl, and the cereal was added. The cereal was stirred until smooth and served with a stainless steel spoon. Preparation for infant evaluation was similar except that the cereals were prepared and served at home in the same manner as for commercial infant cereals by the parent who took part in the texture evaluation.

The consumer texture profile technique (Szczesniak et al., 1975) was used to evaluate the texture of gruels by adults. For this preliminary investigation, 3 adults who had infants ranging in age from 9 to 21 mo of age participated in the evaluation. Each adult was first asked to evaluate an ideal infant gruel on a 1-6 scale where 1 indicates the absence of each of 21 characteristics and 6 indicates its presence to a very high degree (Appendix B). Then each adult received a serving of each gruel, one at a time. Order of presentation of the gruel samples was randomized. Water was provided for rinsing the mouth between samples.

Each adult evaluated the four cereals in each of two replications. At the end of the second replication, the adults again were asked to evaluate an ideal infant gruel. The ideal evaluations were averaged to give the ideal with which the experimental gruels were compared.

After the second replication, the adults took home packages of each of the four cereals to prepare and feed to their infants. They were asked to evaluate their infants' apparent acceptance of the product as explained in the infant score card in Appendix B. Other questions concerning factors that may influence the use of cereals in the infants' diets also were asked. Order of use of the cereal samples (randomized) was specified. Each of the four cereals was presented to the infants only once.

CHAPTER IV

RESULTS AND DISCUSSION

Model System

Water Absorption

Water absorption of the four soy protein concentrates, calculated as a percentage of the original sample weight on the as-is basis, was evaluated with variations in temperature, type of calcium salt and level of calcium. Mean square values and significance levels are reported in Table 10. The effects of soy concentrate, temperature, calcium salt and and level of calcium and their second order interactions were significant ($P<0.0001$).

Effect of type of soy concentrate. Water absorption values for the grit concentrates, Promosoy 20/60 and Ardex 700G, were consistently higher than those for the powder concentrates, Promosoy-100 and Ardex 700F (Table 11). Promosoy-100 had the lowest values overall.

Effect of temperature. Water absorption of the concentrates was higher at 50°C than at ambient temperature (Table 11). That this tended to be true for all soy concentrate-calcium salt-calcium level combinations is shown by the values in Tables A-3 and A-4 (Appendix A), as well as by comparison of Figures 1-4 with Figures 5-8. The significant interaction between soy concentrate and temperature reflects the smaller effect of temperature on water absorption of the Ardex soys than on that of the Promosoys (Table 11).

Table 10--Mean square values and significance of F-ratios for water absorption and Brookfield consistency in the model system

Source	df	Water Absorption	Brookfield Consistency
Total	255		
Soy concentrate (S)	3	89,678.82***	3,579,102.89***
Temperature (T)	1	51,726.43***	478,258.69***
S x T	3	3,844.91***	257,425.93***
Block (S x T) (error term a)	16	273.45***	11,701.08***
Calcium salt (C)	3	31,665.19***	144,747.86***
S x C	9	614.52***	70,786.64***
T x C	3	297.97***	13,576.00**
S x T x C	9	60.78[NS]	4,662.84*
Level of calcium (L)	3	44,194.76***	139,164.51***
S x L	9	685.41***	56,352.18***
T x L	3	1,162.43***	14,688.03**
S x T x L	9	466.33***	4,159.70*
C x L	8[a]	3,773.26***	17,348.16***
S x C x L	24[a]	95.18**	5,931.51***
T x C x L	8[a]	51.98[NS]	3,537.30[NS]
S x T x C x L	24[a]	26.86[NS]	3,255.78[NS]
Residual (error term b)	112	38.35	1,815.30

*P<0.05.

**P<0.01.

***P<0.0001.

[NS]P>0.05.

[a]Degrees of freedom lost because of confounding of block.

Table 11--Water absorption[a] in the model system as affected by soy concentrate and temperature

Temperature	Soy Concentrate				Mean
	Promosoy-100	Promosoy 20/60	Ardex 700F	Ardex 700G	
	%				
Ambient	251.0	324.4	289.7	339.6	301.2
50°C	287.6	369.7	311.2	349.8	329.6
Mean	269.3	347.0	300.4	344.7	

[a]Each value is an average of 32 measurements (4 calcium salts x 4 levels of calcium x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block.

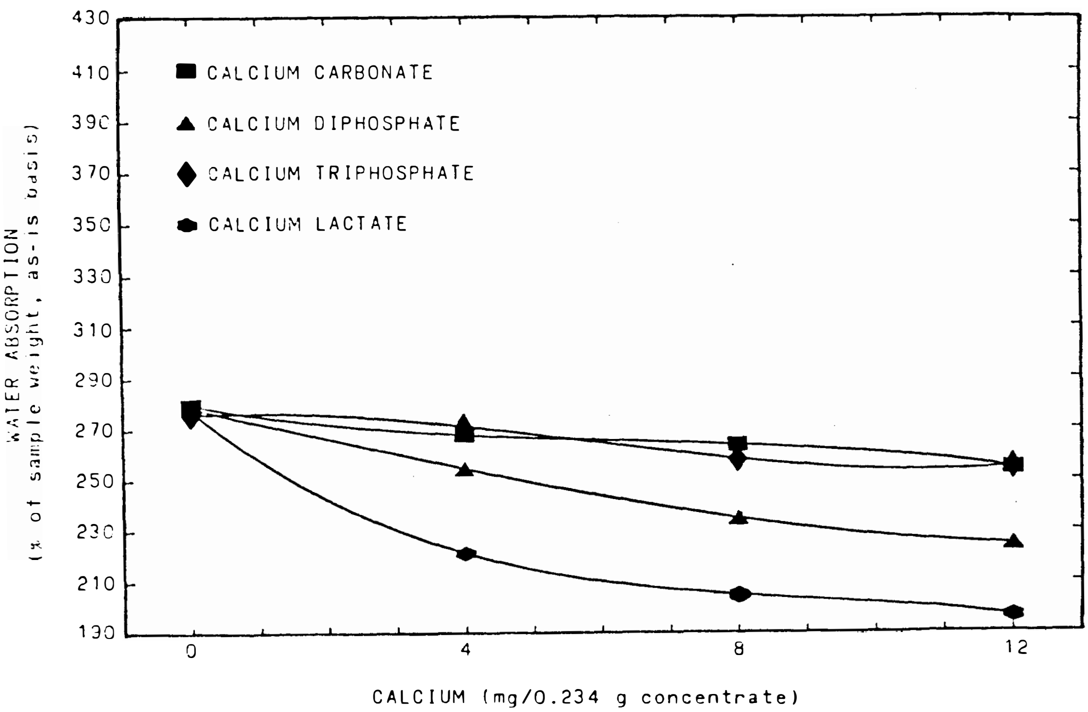

Fig. 1--Water absorption of Promosoy-100 at ambient temperature as affected by type of calcium salt and level of calcium.

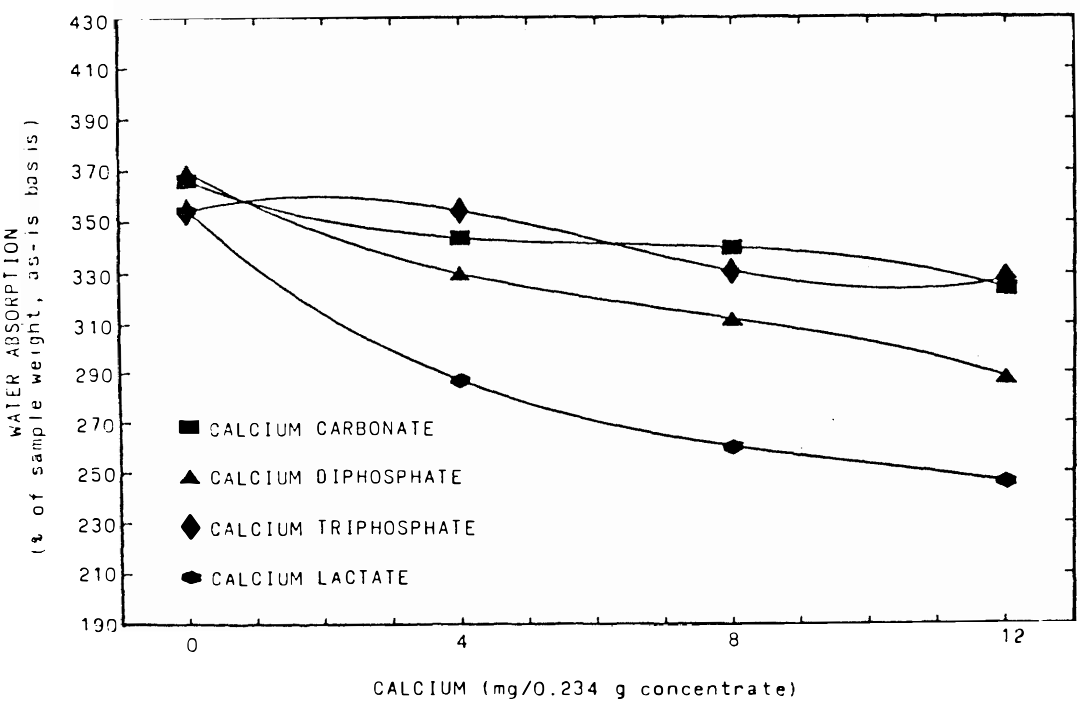

Fig. 2--Water absorption of Promosoy 20/60 at ambient temperature as affected by type of calcium salt and level of calcium.

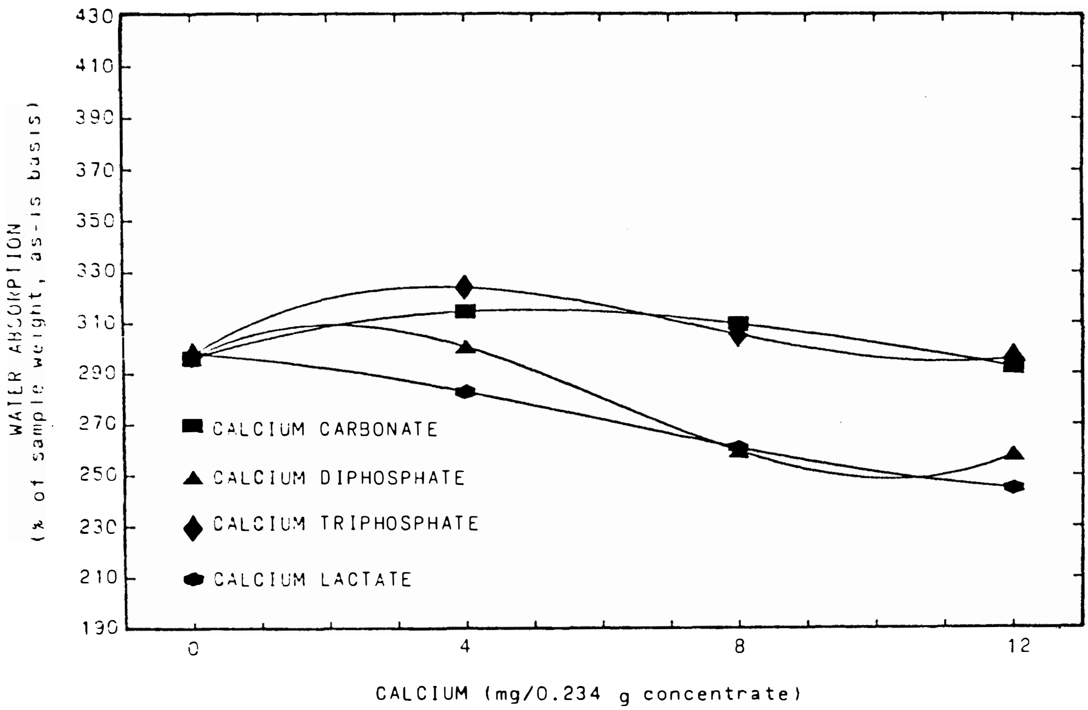

Fig. 3--Water absorption of Ardex 700F at ambient temperature as affected by type of calcium salt and level of calcium.

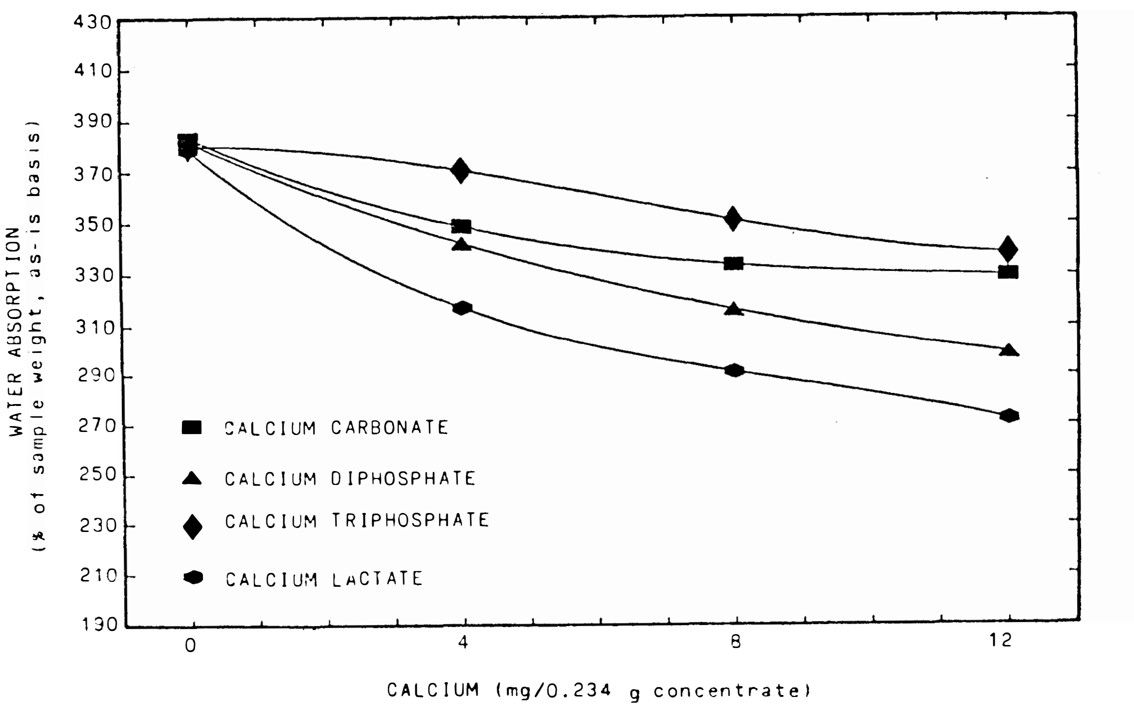

Fig. 4--Water absorption of Ardex 700G at ambient temperature as affected by type of calcium salt and level of calcium.

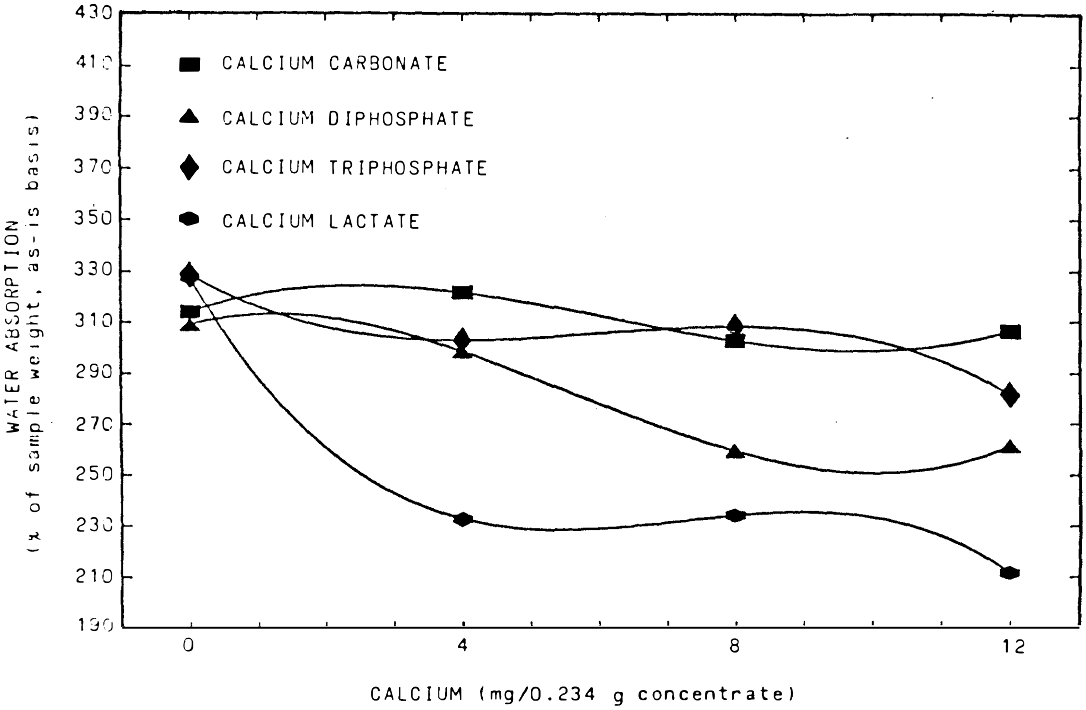

Fig. 5--Water absorption of Promosoy-100 at 50^{O}C as affected by type of calcium salt and level of calcium.

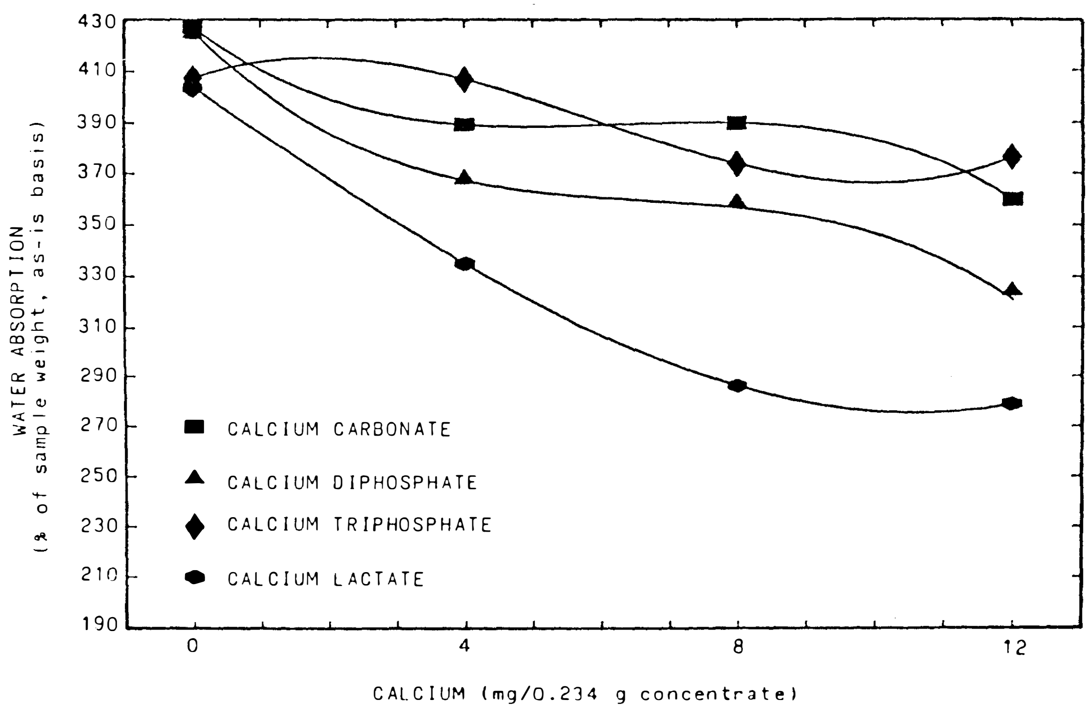

Fig. 6--Water absorption of Promosoy 20/60 at 50^{O}C as affected by type of calcium salt and level of calcium.

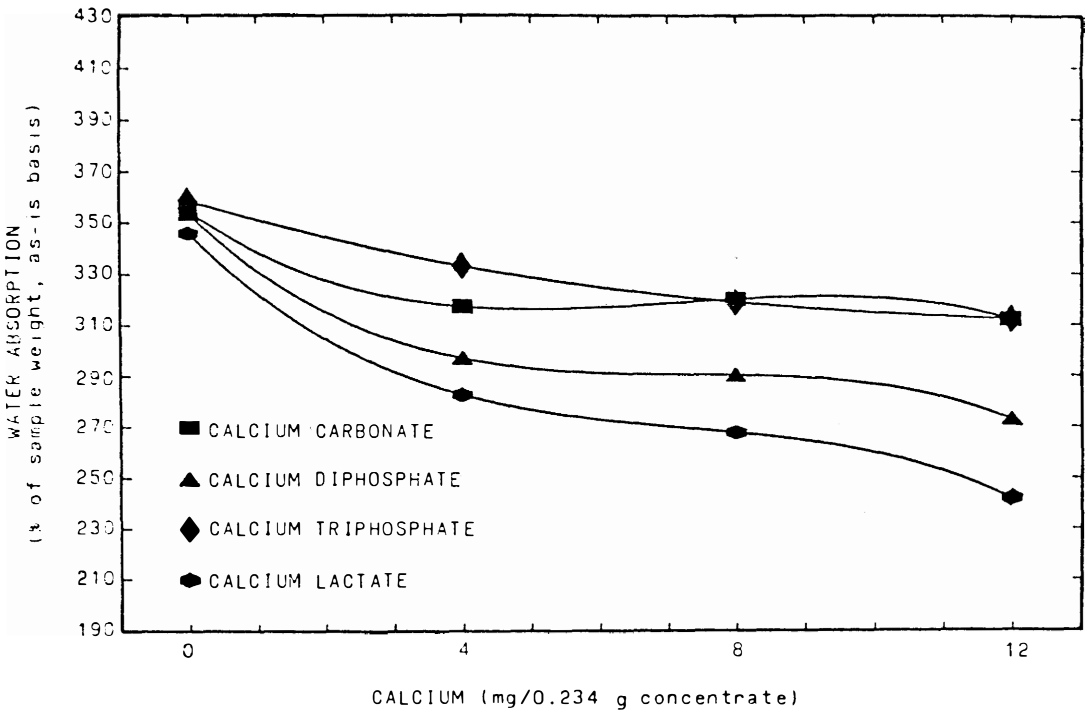

Fig. 7--Water absorption of Ardex 700F at 50^{o}C as affected by type of calcium salt and level of calcium.

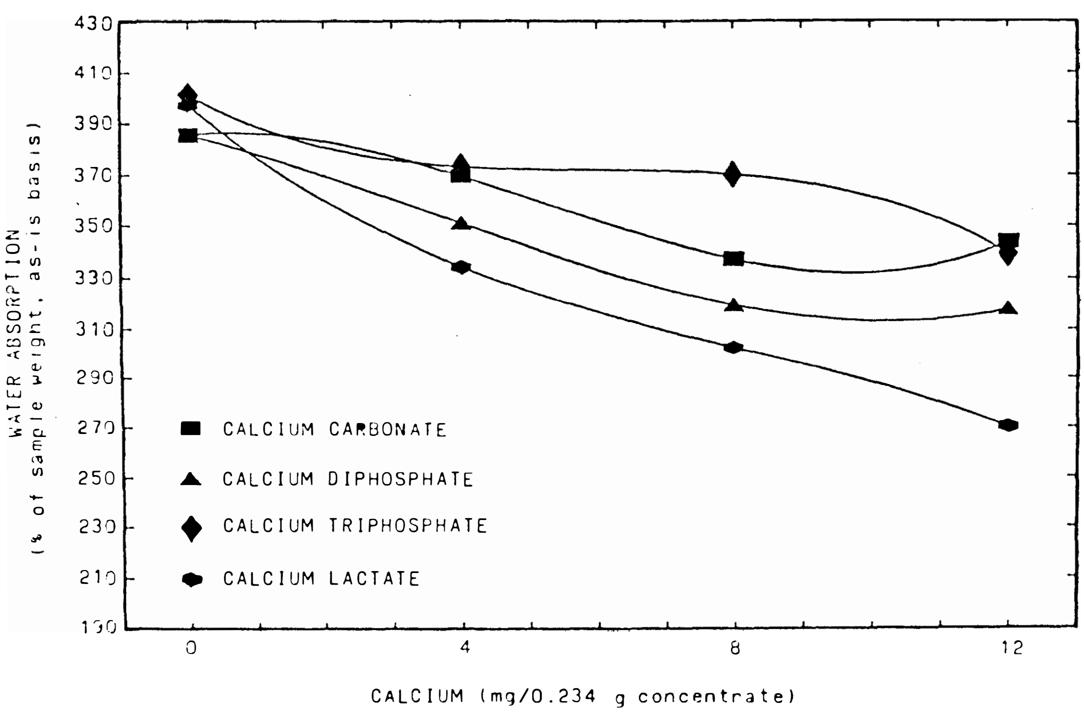

Fig. 8--Water absorption of Ardex 700G at 50^{o}C as affected by type of calcium salt and level of calcium.

<u>Effect of calcium.</u> Concentrates absorbed the most water in the presence of calcium carbonate and calcium phosphate tribasic and absorbed the least water in the presence of calcium lactate, according to overall means (Table 12). Water absorption was maximum when no calcium was added to the concentrate and generally decreased with increasing level of calcium (Table 12). However, a significant interaction between calcium salt and calcium level is evidenced by the differences in shapes of the curves for the four calcium salts within each graph (Figures 1-8), as well as by differences in magnitude of effects. Calcium carbonate and calcium phosphate tribasic had minimum effects on water absorption with increasing level of calcium, whereas calcium lactate had the greatest effect in decreasing water absorption values with increasing level of calcium (Table 12).

Table 12--Water absorption[a] in the model system as affected by calcium salt and level of calcium

Calcium Salt	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
	%				
Calcium carbonate	350.9	334.0	324.7	315.3	331.2
Calcium phosphate dibasic	350.1	317.8	293.8	280.8	310.6
Calcium phosphate tribasic	350.4	342.0	327.0	315.8	333.8
Calcium lactate	348.0	286.6	263.4	245.2	285.8
Mean	349.8	320.1	302.2	289.3	

[a]Each value is an average for 16 measurements (4 soy concentrates x 2 temperatures x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block.

In general, the type of calcium salt had less effect on the water absorption of the Ardex concentrates than on that of the Promosoy concentrates as shown by the respective ranges between means in Table 13. However, the level of calcium had less effect on the water absorption of powder concentrates, Promosoy-100 and Ardex 700F, than on that of the grit concentrates, Promosoy 20/60 and Ardex 700G, as indicated by the respective ranges between means in Table 14.

Table 13--Water absorption[a] in the model system as affected by soy concentrate and calcium salt

	Calcium Salt				
Soy Concentrate	Carbonate	Phosphate Dibasic	Phosphate Tribasic	Lactate	Mean
	%				
Promosoy-100	288.8	265.0	285.2	238.2	269.3
Promosoy 20/60	367.7	347.4	366.4	306.6	347.0
Ardex 700F	314.6	291.0	318.2	278.1	300.5
Ardex 700G	353.9	339.1	365.4	320.4	344.7
Mean	331.2	310.6	333.8	285.8	

[a]Each value is an average for 16 measurements (2 temperatures x 4 levels of calcium x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block.

There also were significant interactions between temperature and calcium salt and between temperature and level of calcium. Temperature appears to have a somewhat smaller effect on water absorption in the presence of calcium lactate than in the presence of the other salts

Table 14--Water absorption[a] in the model system as affected by soy concentrate and level of calcium

Soy Concentrate	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
	%				
Promosoy-100	299.0	271.3	258.2	248.8	269.3
Promosoy 20/60	388.6	352.0	331.6	315.8	347.0
Ardex 700F	325.1	306.4	291.5	278.8	300.4
Ardex 700G	386.7	350.8	327.6	313.7	344.7
Mean	349.8	320.1	302.2	289.3	

[a]Each value is an average for 16 measurements (2 temperatures x 4 calcium salts x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block.

(Table 15). Temperature also had a somewhat smaller effect on water absorption when calcium was added to the concentrates that when no calcium was present (Table 16).

Brookfield Consistency

Direct comparisons of the values obtained with the Brookfield viscometer are appropriate because it was possible to use the same spindle and speed for all measurements. However, Promosoy 20/60 suspensions began to separate before measurements were completed, so these values need to be compared with those for other soy concentrates with caution.

Table 15--Water absorption[a] in the model system as affected by temperature and calcium salt

Temperature	Calcium Salt				Mean
	Carbonate	Phosphate Dibasic	Phosphate Tribasic	Lactate	
	%				
Ambient	315.4	296.6	318.1	274.6	301.2
50°C	347.0	324.7	349.5	297.0	329.6
Mean	331.2	310.6	333.8	285.8	

[a]Each value is an average of 32 measurements (4 soy concentrates x 4 levels calcium x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block

Table 16--Water absorption[a] in the model system as affected by temperature and level of calcium

Temperature	Calcium Level (mg/0.234 g concentrate)				Mean
	0	4	8	12	
	%				
Ambient	329.3	308.1	289.4	277.8	301.2
50°C	370.4	332.1	315.0	300.7	329.6
Mean	349.8	320.1	302.2	289.2	

[a]Each value is an average for 32 measurements (4 soy concentrates x 4 calcium salts x 2 replications). Values are a summary of those presented in Tables A-3 and A-4 (Appendix A), which have been adjusted for effect of block.

Mean squares and significance levels for Brookfield consistency of the suspensions of the four soy protein concentrates are reported in Table 10, page 46. Differences in Brookfield consistency attributable to the main effects of soy concentrate, temperature, calcium salt and level of calcium and to most second order effects were significant at the level $P<0.0001$. The interactions between temperature and calcium salt and between temperature and level of calcium were significant at the level $P<0.01$. The significance of higher order interactions also is given in Table 10.

Effect of type of soy concentrate. Suspensions of grit concentrates, Promosoy 20/60 and Ardex 700G, were consistently more viscous than those of the powder concentrates, Promosoy-100 and Ardex 700F (Tables 17 and A-5 and A-6, Appendix A). Suspensions of Promosoy-100 had the lowest Brookfield consistency values. Promosoy 20/60 had the highest values overall but these might have been influenced by the above-mentioned tendency for this concentrate to settle during the measurement. The differences among the concentrates may be seen also in the graphs (Figures 9-16), but certain comparisons are difficult because the y-axis scales differ between the powder and grit concentrates.

Effect of temperature. The suspensions held at 50°C were more viscous than those held at ambient temperature (Table 17), except those of Ardex 700F which were less viscous at the higher temperature at all calcium salt-calcium level combinations (Figures 11 and 15 and Table A-6, Appendix A). Temperature affected Brookfield consistency of Promosoy 20/60 suspensions the most (Table 17).

Table 17--Brookfield consistency[a] in the model system as affected by soy concentrate and temperature

Temperature	Soy Concentrate				Mean
	Promosoy-100	Promosoy 20/60	Ardex 700F	Ardex 700G	
	---------- cps ----------				
Ambient	39.8	475.9	246.3	335.3	274.3
50°C	51.8	721.8	207.5	462.0	360.8
Mean	45.8	598.8	226.9	398.6	

[a]Each value is an average for 192 measurements (4 calcium salts x 4 levels of calcium x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

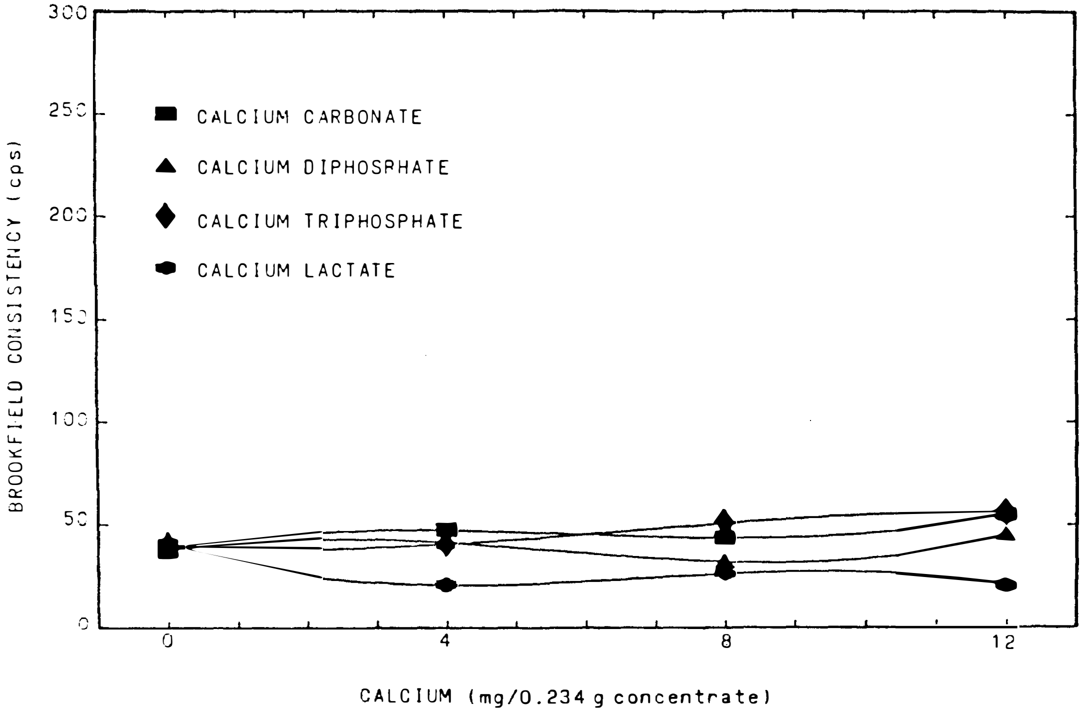

Fig. 9--Brookfield consistency of Promosoy-100 suspensions at ambient temperature as affected by type of calcium salt and level of calcium.

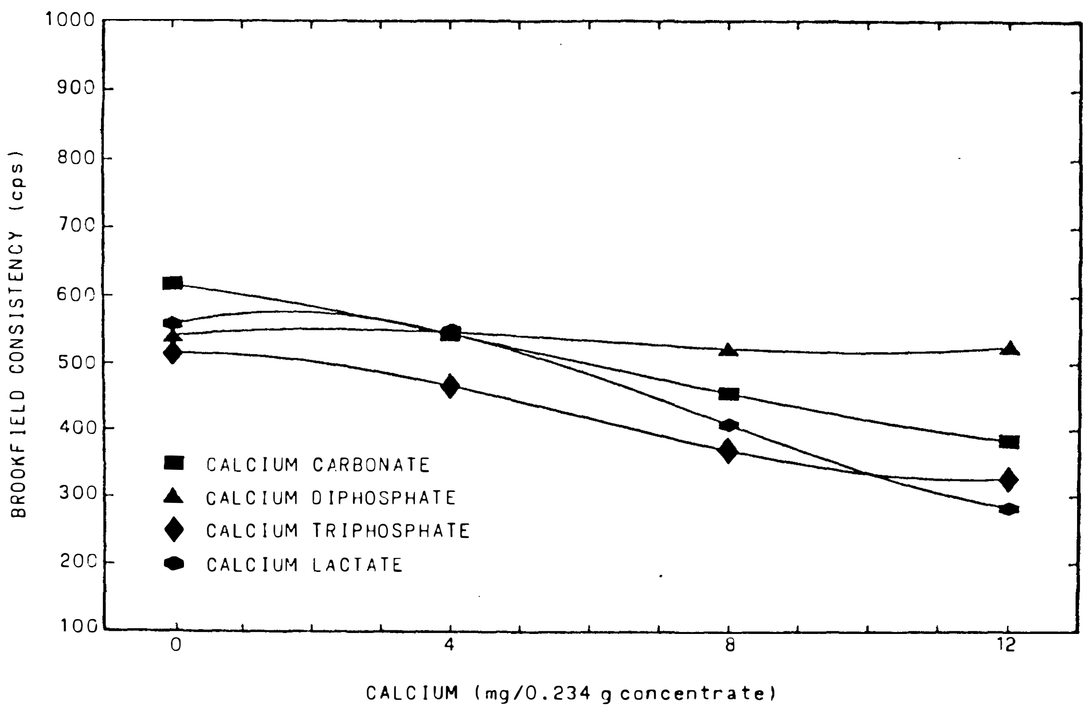

Fig. 10--Brookfield consistency of Promosoy 20/60 suspensions at ambient temperature as affected by type of calcium salt and level of calcium.

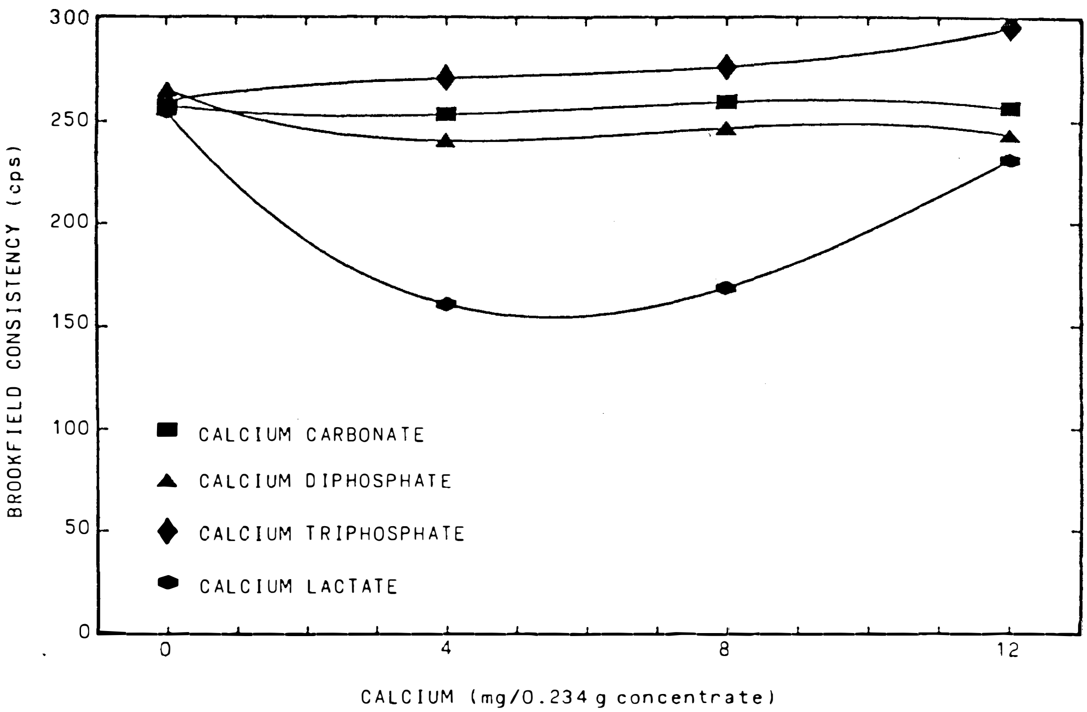

Fig. 11--Brookfield consistency of Ardex 700F suspensions at ambient temperature as affected by type of calcium salt and level of calcium.

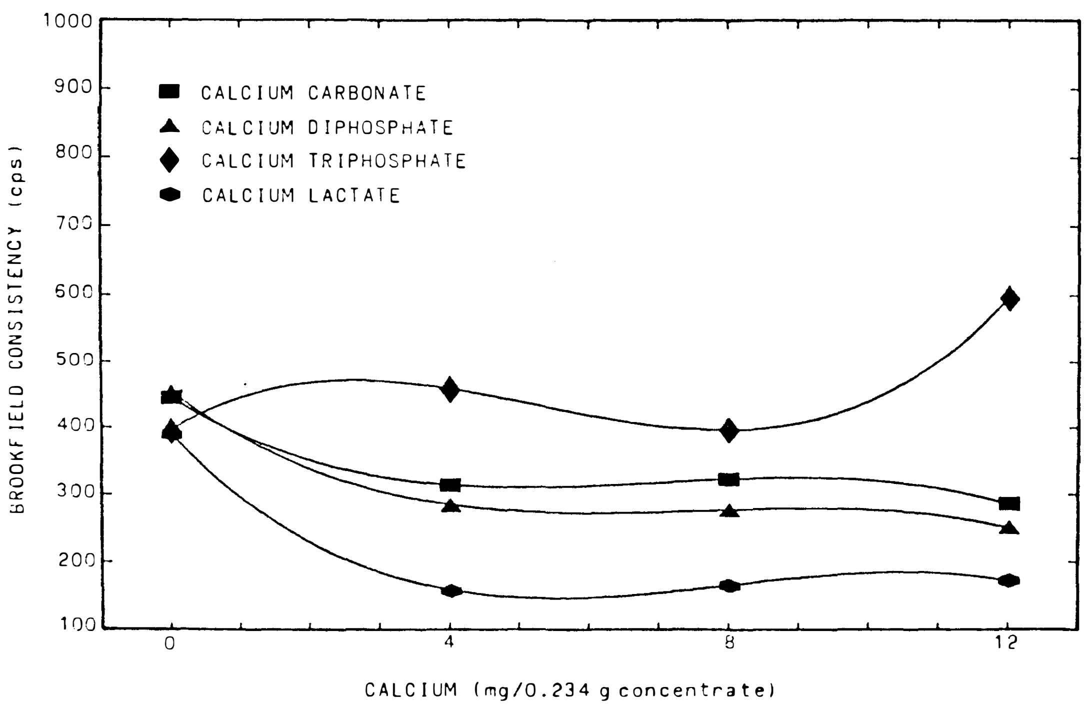

Fig. 12--Brookfield consistency of Ardex 700G suspensions at ambient temperature as affected by type of calcium salt and level of calcium.

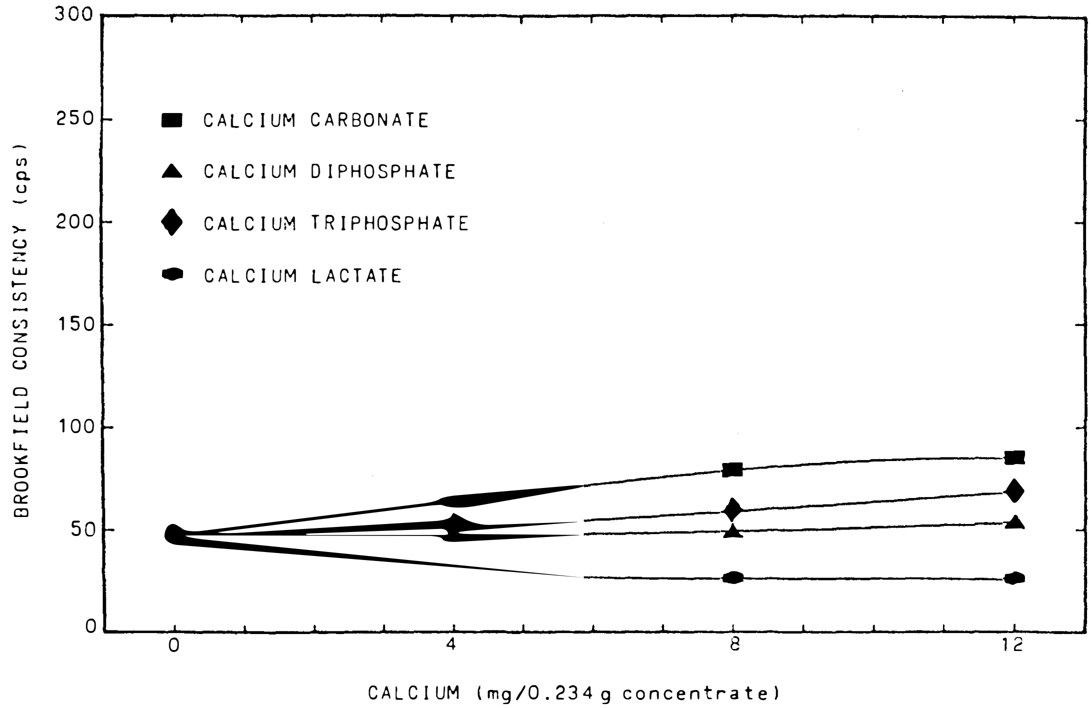

Fig. 13--Brookfield consistency of Promosoy-100 suspensions at 50°C as affected by type of calcium salt and level of calcium.

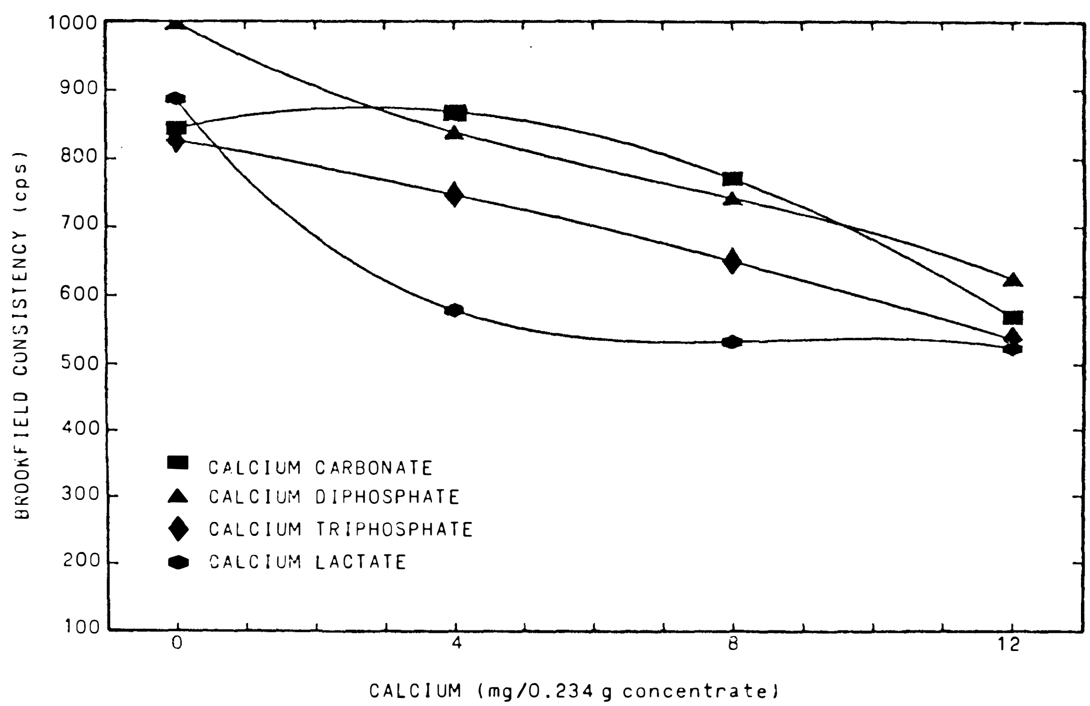

Fig. 14--Brookfield consistency of Promosoy 20/60 suspensions at 50°C as affected by type of calcium salt and level of calcium.

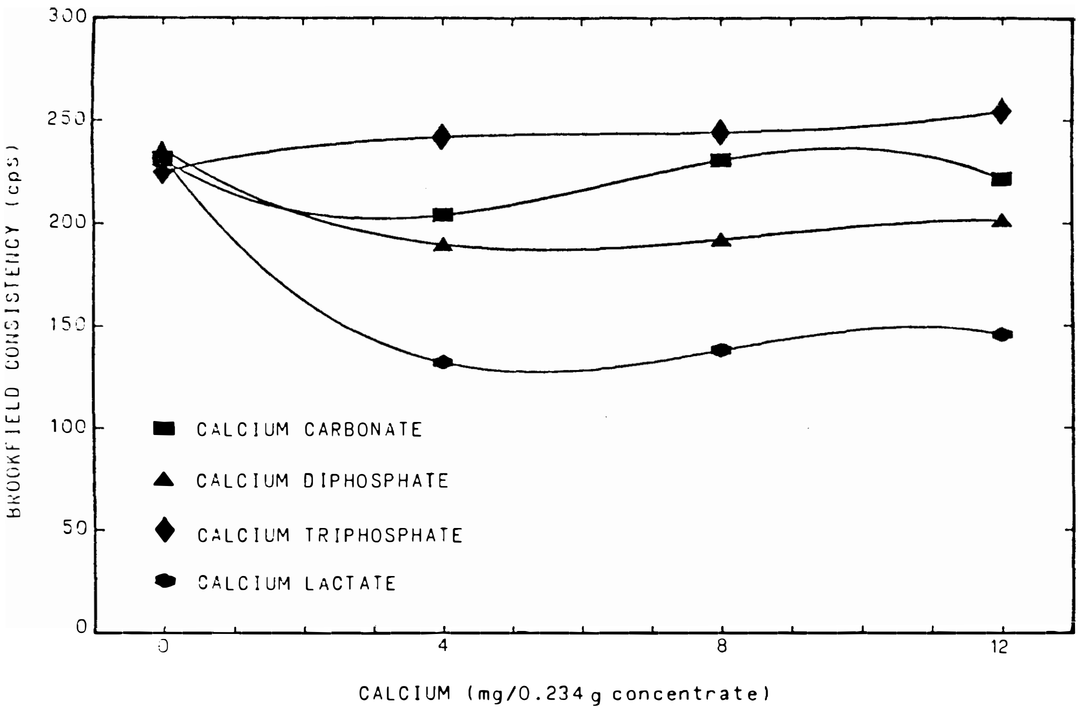

Fig. 15--Brookfield consistency of Ardex 700F suspensions at 50^{o}C as affected by type of calcium salt and level of calcium.

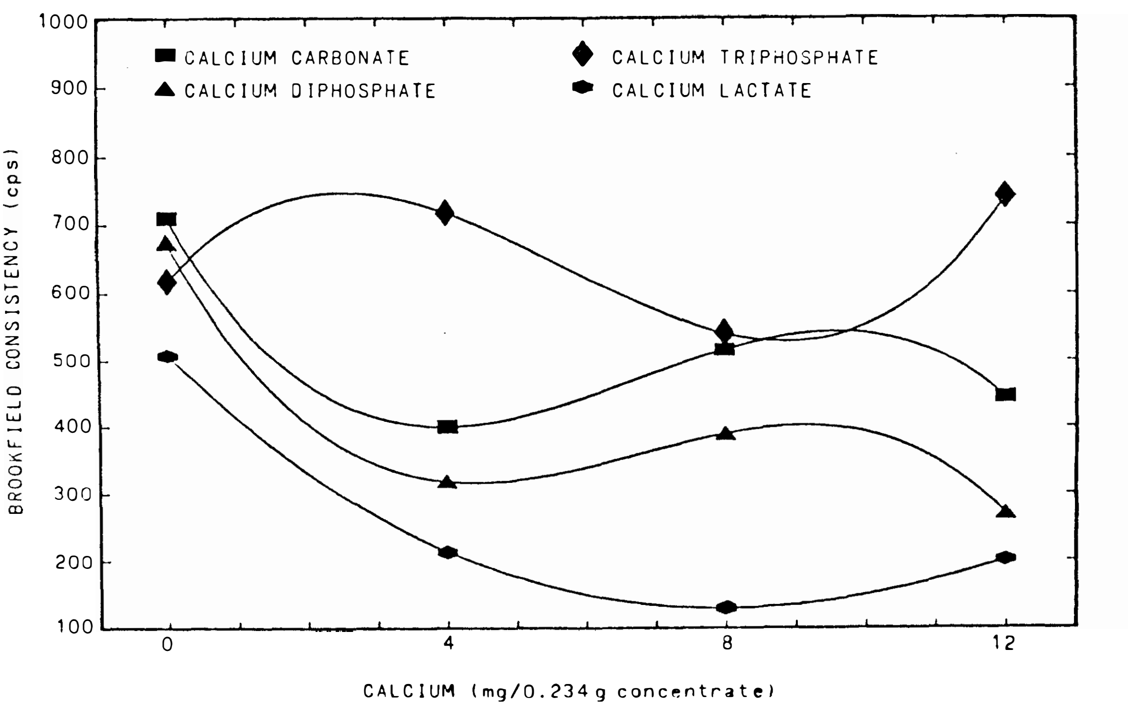

Fig. 16--Brookfield consistency of Ardex 700G suspensions at 50^{o}C as affected by type of calcium salt and level of calcium.

Effect of calcium. Both calcium salt and calcium level had varied effects on Brookfield consistency. Concentrate suspensions containing calcium phosphate tribasic were the most viscous, and those containing calcium lactate were the least viscous, according to overall means (Table 18). Brookfield consistency was maximum when no calcium was added to the concentrate and decreased, in general, with increasing levels of calcium, according to overall means (Table 18). However, the effect of calcium phosphate tribasic did not conform to this general pattern. The significant interaction between calcium salt and calcium level can be seen also by the differences in shapes of the curves for the four calcium salts within each graph (Figures 9-16). Furthermore, increasing levels of calcium carbonate and calcium phosphate dibasic from 4 to 8 mg of calcium had relatively little effect on Brookfield consistency, whereas the effect of increased calcium lactate was smallest between the 8 and 12 mg levels of calcium (Table 18).

The significant interactions between calcium salt and soy concentrate and between level of calcium and soy concentrate are indicated by the differences in respective ranges among the means for each concentrate and by the varied effects of specific calcium salts and levels of calcium (Tables 19 and 20). Ardex 700G suspension was affected most by the calcium salts (Table 19). In general, the grit concentrate suspensions, Promosoy 20/60 and Ardex 700G, were affected more by the level of calcium than were the powder concentrate suspensions, Promosoy-100 and Ardex 700F. In addition, the concentrate suspensions differed in the magnitude and direction of their responses to specific salt increments (Table 20).

Table 18--Brookfield consistency[a] in the model system as affected by calcium salt and level of calcium

Calcium Salt	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
	cps				
Calcium carbonate	399.1	337.0	335.1	287.4	339.6
Calcium phosphate dibasic	407.2	313.4	306.6	276.7	326.0
Calcium phosphate tribasic	366.2	374.3	323.6	359.4	355.9
Calcium lactate	365.1	229.7	199.4	200.2	248.6
Mean	384.4	313.6	291.2	280.9	

[a]Each value is an average for 96 measurements (4 soy concentrates x 2 temperatures x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

Table 19--Brookfield consistency[a] in the model system as affected by soy concentrate and calcium salt

Soy Concentrate	Calcium Salt Carbonate	Phosphate Dibasic	Phosphate Tribasic	Lactate	Mean
	cps				
Promosoy-100	57.4	44.2	51.8	29.8	45.8
Promosoy-20/60	632.0	668.2	555.2	539.8	598.8
Ardex 700F	239.3	226.9	258.4	183.0	226.9
Ardex 700G	429.8	364.7	558.2	241.9	398.6
Mean	339.6	326.0	355.9	248.6	

[a]Each value is an average for 96 measurements (2 temperatures x 4 levels of calcium x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

Table 20--Brookfield consistency[a] in the model system as affected by soy concentrate and level of calcium

Soy Concentrate	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
	cps				
Promosoy-100	43.4	42.7	45.8	51.2	45.8
Promosy 20/60	724.2	642.4	557.1	471.7	598.8
Ardex 700F	245.3	211.5	219.6	231.2	226.9
Ardex 700G	524.8	358.0	342.1	369.8	398.7
Mean	384.4	313.6	291.2	281.0	

[a]Each value is an average for 96 measurements (2 temperatures x 4 calcium salts x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

As stated earlier, there also were significant interactions between calcium salt and temperature and between level of calcium and temperature. Temperature affected Brookfield consistency somewhat less in the presence of calcium lactate than in the presence of the other salts (Table 21). Temperature affected Brookfield consistency less when calcium was added to the concentrate suspensions, especially at the 12 mg level, than when no calcium was present (Table 22).

Discussion of Results for the Model System

It is well known that the processing procedures used in the manufacture of a soy product affect the nature of the protein, which in turn affects the functional properties of the final soy product (Kinsella, 1976, 1979). In this study a difference in physical form was

Table 21--Brookfield consistency[a] in the model system as affected by temperature and calcium salt

Temperature	Calcium Salt				Mean
	Carbonate	Phosphate Dibasic	Phosphate Tribasic	Lactate	
	cps				
Ambient	286.3	284.7	301.0	225.2	274.3
50°C	393.0	367.3	410.8	272.0	360.8
Mean	339.7	326.0	355.9	248.6	

[a]Each value is an average for 192 measurements (4 soy concentrates x 4 levels of calcium x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

Table 22--Brookfield consistency[a] in the model system as affected by temperature and level of calcium

Temperature	Calcium Level (mg/0.234 g concentrate)				Mean
	0	4	8	12	
	cps				
Ambient	319.6	274.6	251.5	251.6	274.3
50°C	449.2	352.7	330.8	310.4	360.8
Mean	384.4	313.6	291.2	281.0	

[a]Each value is an average for 192 measurements (4 soy concentrates x 4 calcium salts x 2 replications x 3 subsamples x 2 readings). Values are a summary of those presented in Tables A-5 and A-6 (Appendix A), which have been adjusted for effect of block.

superimposed on the more subtle differences among the concentrates. Johnson (1970) and Wolf and Cowan (1971) indicated that particle size and distribution may influence the rate of water absorption; however, the effect of particle size on the total extent of absorption was not discussed. Johnson (1970) also mentioned an effect of particle size on the rate of development of viscosity and on final viscosity but did not elaborate on the overall nature of the effect. In spite of numerous interactions observed in the study reported herein, it can be generalized that water absorption was greater for the grits studied than for the powders and that suspensions of grits were more viscous than were suspensions of powders; the powder Promosoy-100 had the lowest values for both water absorption and Brookfield consistency.

The above generalizations support a previously suggested (Kinsella, 1979) relationship between water absorption and viscosity. Further support is seen in many of the responses to the other variables. The responses may be summarized as follows:

1. Water absorption was consistently higher at 50°C than at ambient temperature; suspension consistency also was higher at 50°C than at ambient temperature (unexplained exception: the Ardex 700F suspensions were less viscous at 50°C than at ambient temperature).
2. Temperature had a somewhat smaller effect on both water absorption and suspension consistency in the presence of calcium than in its absence.
3. Temperature had a somewhat smaller effect on both water absorption and suspension consistency in the presence of calcium lactate than in the presence of other salts.

4. Concentrates tended to absorb the most water in the presence of calcium carbonate and calcium phosphate tribasic and the least in the presence of calcium lactate; concentrate suspensions containing calcium phosphate tribasic were most viscous and suspensions containing calcium lactate were least viscous overall.
5. Water absorption and suspension consistency both decreased overall with increasing level of calcium; however, other variables affected the response to calcium level considerably.
6. The level of calcium tended to affect both water absorption and suspension viscosity of grit concentrates more than those properties of powder concentrates.

Hutton and Campbell (1977a,b) and Wolf and Cowan (1971) also reported parallel effects of certain variables on water absorption and suspension consistency of soy concentrates and isolates.

Hermansson (1979) describes water binding by proteins as involving several processes, including swelling, unfolding of molecules and consequent exposure of additional binding sites. The unfolding of molecules also can be expected to result in increased suspension consistency because of increased molecular axial ratios and hydrodynamic volumes.

The greater water absorption and suspension consistency at 50°C than at ambient temperature could reflect the effect of heat on the unfolding of protein molecules. The lower water absorption in the presence of calcium salts than in their absence could result from their competing with water for binding sites on the protein molecules. The lower consistency overall in the presence of calcium salts could result from reduced

zeta potential and, therefore, reduced thickness of the electric double layer resulting in lower effective particle size. The overall effect of increasing salt level could be explained similarly. Differences among the calcium salts could be related to differences in their solubility and/or ionic strengths. Calcium lactate is much more water-soluble than are the other calcium salts studied; therefore, the lowest water absorption overall in the presence of calcium lactate could simply reflect greater availability of a substance to compete with water for binding sites on protein molecules. In order to keep levels of calcium equal for all salts, it was necessary to use quite different amounts of the salts, as explained in the Procedure. Furthermore, the salts differed greatly in their solubility as indicated above, and the amounts of calcium carbonate, calcium phosphate di- and tribasic used actually exceeded the limits of their theoretical solubility. When solubility was taken into account in calculation of the ionic strengths of the salt solutions involved in viscosity measurements, the relationships among the ionic strengths were as follows: calcium lactate > calcium phosphate dibasic > calcium phosphate tribasic > calcium carbonate. Therefore, it seems possible that the concentrate suspensions containing calcium lactate were least viscous overall because of the highest ionic strength of its solutions.

The numerous interactions observed indicate that the relationships among the variables studied are more complex than is suggested by the preceding statements. The above explanations, therefore, probably represent an oversimplification.

Food System

Water absorption, Brookfield consistency and Bostwick consistency of corn-soy cereal containing pregelatinized corn meal and a selected powder or grit concentrate were the objective measurements of the food system. Each of the 2 selected concentrates was used in cereals prepared with all 16 calcium salt-calcium level combinations. PER and Kjeldahl analyses were used to evaluate the nutritional quality of corn-soy cereals prepared from the same selected concentrates and one selected level of all four calcium salts. A preliminary consumer panel also was conducted to evaluate the gruel with variation of type of calcium salt.

The results for the model system were useful for screening soy concentrates and other variables for potential use in the food system, a corn-soy blend that is designed for use as a gruel or infant weaning food. It was evident (Table 11, p. 47, Table 17, p. 57, Figures 1-8, pp. 48-51, and Figures 9-16, pp. 58-61) that temperature affected the properties of the model system. Therefore, water absorption and Brookfield consistency of the corn-soy cereal were tested at 50°C, although Bostwick consistency, for comparison purposes, was tested on cooked gruel cooled to 30°C in the manner specified by USDA (1978) for CSB; additional Brookfield measurements were made on these same cooked samples at 30°C.

Both a powder and grit concentrate were tested in the food system in order to determine whether these products would show similar properties and whether they could be used interchangeably in the formulation of the corn-soy cereal. An arbitrary decision was made to select a powder and grit from the same commercial source. The properties of Ardex concentrates were more similar than were those of the Promosoy concentrates

and their water absorption and Brookfield consistency properties responded less drastically to the variables studied; therefore, the two Ardex concentrates were used in the corn-soy cereals that were subjected to objective and nutritional evaluation.

Properties of Corn-Soy Cereal

Water absorption. The results of the analysis of variance for water absorption are not shown because the only significant effects were those of soy concentrate ($P<0.0001$) and calcium salt ($P<0.05$). The cereal containing grit concentrate, corn-Ardex 700G cereal, absorbed somewhat more water overall than did the cereal containing powder concentrate, corn-Ardex 700F, as shown in Table 23 and in Figures 17 and 18. (Note that the *y*-axis scales differ.) Cereals containing calcium carbonate absorbed the most water, and those containing calcium lactate absorbed the least water, according to overall means (Table 23).

Table 23--Water absorption[a] of cereals as affected by soy concentrate and calcium salt

Cereal	Calcium Salt				Mean
	Carbonate	Phosphate Dibasic	Phosphate Tribasic	Lactate	
	%				
Corn-soy Ardex 700F	196.9	192.2	195.6	187.0	192.9
Corn-soy Ardex 700G	211.8	201.4	199.6	186.8	199.9
Mean	204.4	196.8	197.6	186.9	

[a]Each value is an average for 8 measurements (4 levels of calcium x 2 replications). Values are a summary of those presented in Table A-7 (Appendix A), which have been adjusted for effect of block.

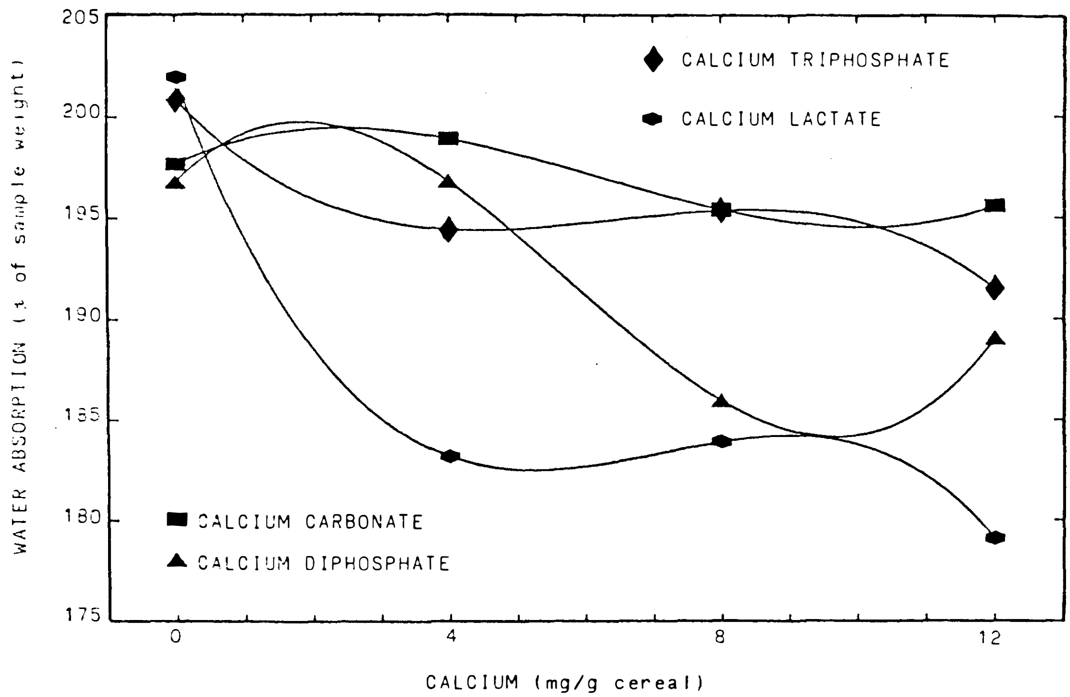

Fig. 17--Water absorption of corn-Ardex 700F cereal as affected by type of calcium salt and level of calcium.

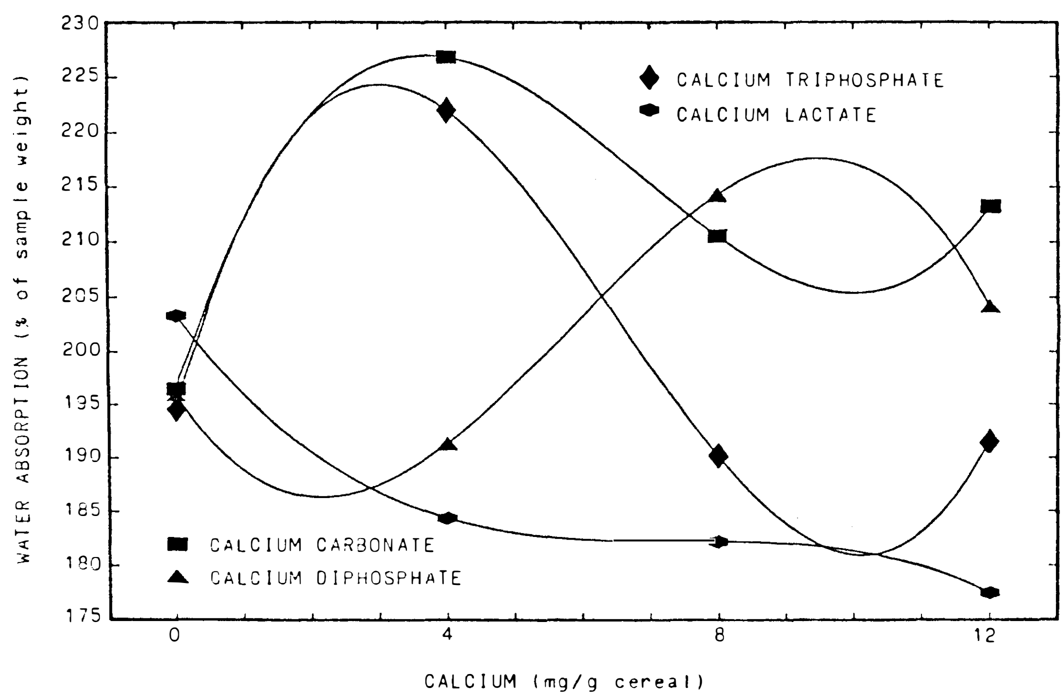

Fig. 18--Water absorption of corn-Ardex 700G cereal as affected by type of calcium salt and level of calcium.

Brookfield consistency of uncooked cereal suspensions. Brookfield consistency values of uncooked cereal suspensions were significantly affected only by soy concentrate ($P<0.0001$). Corn-Ardex 700G cereal suspensions were more viscous than corn-Ardex 700F cereal suspensions as seen in the overall means in Table A-7 (Appendix A) and in comparison of Figure 19 with Figure 20. (Note that the y-axis scales differ.) No other variables studied had significant effects.

Bostwick and Brookfield consistency of cooked gruel. Even though Brookfield measurements had already been made on the uncooked food system, it was desired to determine whether the Brookfield viscometer could be used in place of the Bostwick consistometer in measuring consistency of cooked gruel as specified by the USDA (1978) for CSB.

Bostwick consistency values were significantly affected only by soy concentrate ($P<0.05$). Cooked 700G gruels had slightly higher Bostwick consistency values overall than did cooked 700F gruels. However, effects of concentrate probably are not of practical importance. Values for 13% suspensions of the corn-Ardex 700F cereal ranged between 13.8 and 17.6 and of the corn-Ardex 700G cereal between 14.2 and 17.7 cm/min (Table A-8, Appendix A). These values suggest that the powder and grit concentrate were sufficiently similar in Bostwick consistency and could be used interchangeably in the formulation of the corn-soy cereal. The USDA's (1978) requirements for Bostwick consistency values are 9.0 to 21.0 for cooked 11.75% CSB gruel.

The Bostwick consistometer measurements were less sensitive than those made with the Brookfield viscometer as seen in comparison of values

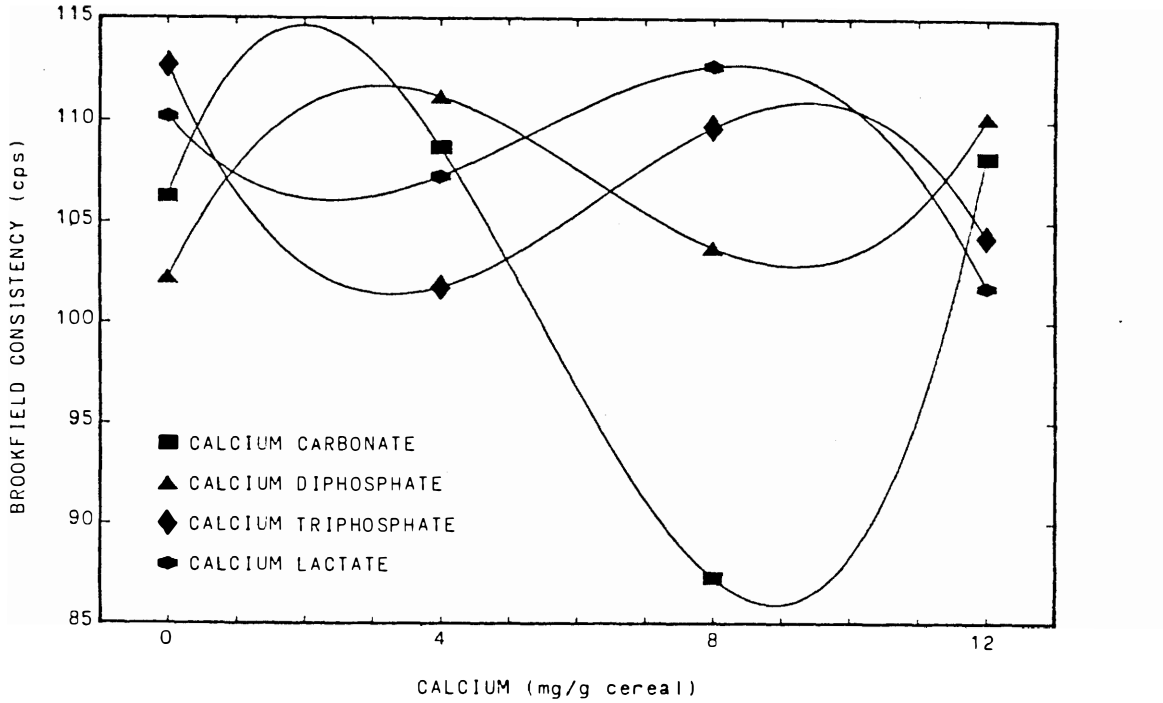

Fig. 19--Brookfield consistency of corn-Ardex 700F cereal suspensions as affected by type of calcium salt and level of calcium.

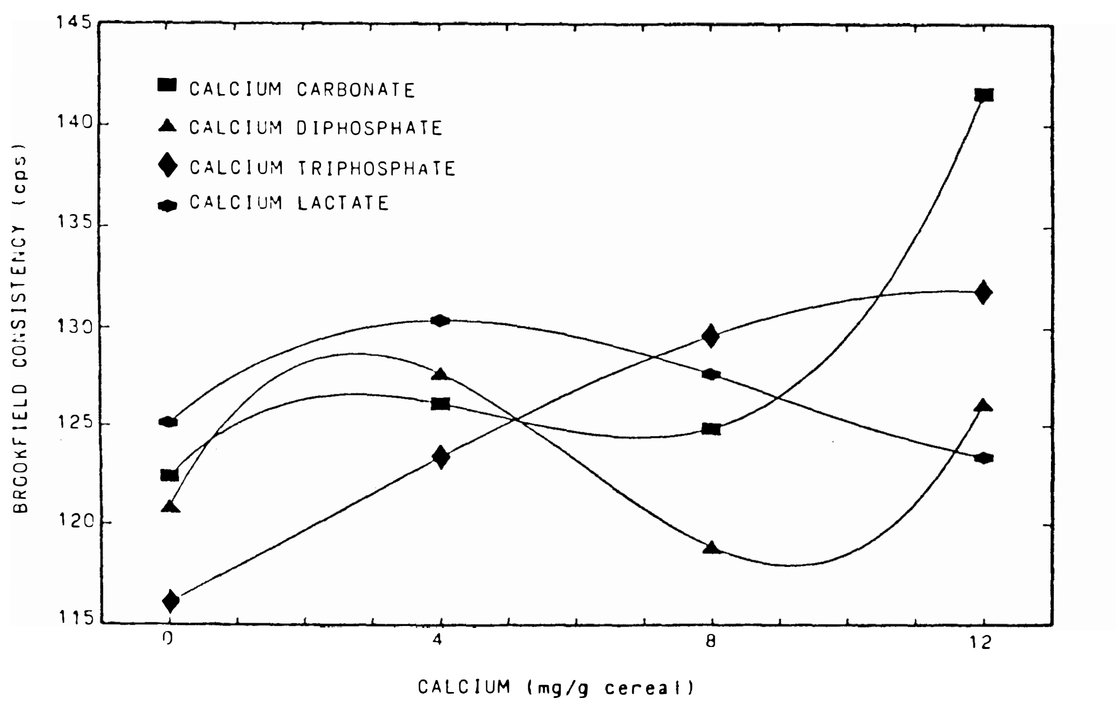

Fig. 20--Brookfield consistency of corn-Ardex 700G cereal suspensions as affected by type of calcium salt and level of calcium.

presented in Table A-8 (Appendix A) and in comparison of Figures 21 and 22 with 23 and 24. Differences ($P<0.05$) among calcium salts were detected when consistency was measured with the Brookfield viscometer. Cereals containing calcium carbonate had the highest Brookfield values overall, whereas those containing calcium lactate had the lowest values overall (Table A-8, Appendix A).

Effects of the variables studied showed the same trends for the two consistency measurements as seen in comparison of Figures 21 and 22 with 23 and 24, respectively. The Brookfield viscometer could be used in place of the Bostwick consistometer in measuring consistency; however, since the Brookfield appears to be more sensitive to small product differences, it would be more useful for research and/or product development. Its use is not necessary for quality control or for determining whether specifications of a product are met. The Bostwick appears adequate for these purposes and is a much simpler instrument to operate.

Relation of Model System to Food System

The effects of soy were similar in the model system and the uncooked food system. Grit concentrates and a cereal containing grit concentrate absorbed more water and their suspensions were more viscous than those of counterpart powder concentrates and cereal containing powder concentrate. However, when the gruel food system was cooked, the cereal containing powder concentrate was more viscous as measured by the Bostwick consistometer and the Brookfield viscometer.

Calcium salts had a significant effect on both water absorption and Brookfield consistency of the model system, whereas this effect was evident only for water absorption and Brookfield consistency measurements

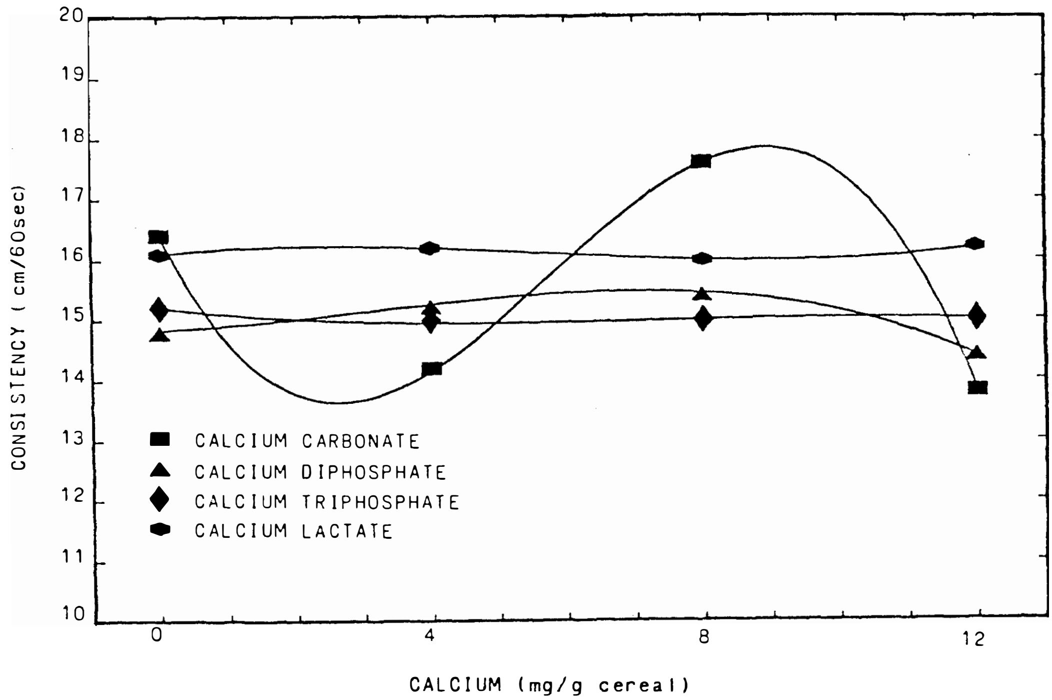

Fig. 21--Bostwick consistency of cooked corn-Ardex 700F gruels as affected by type of calcium salt and level of calcium.

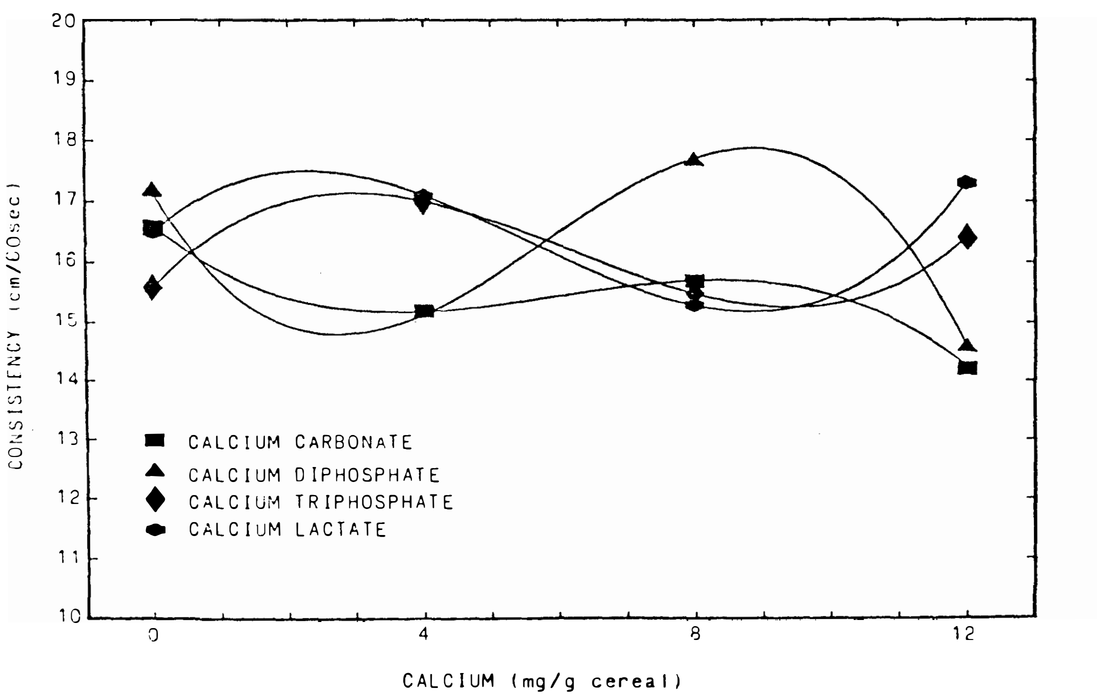

Fig. 22--Bostwick consistency of cooked corn-Ardex 700G gruels as affected by type of calcium salt and level of calcium.

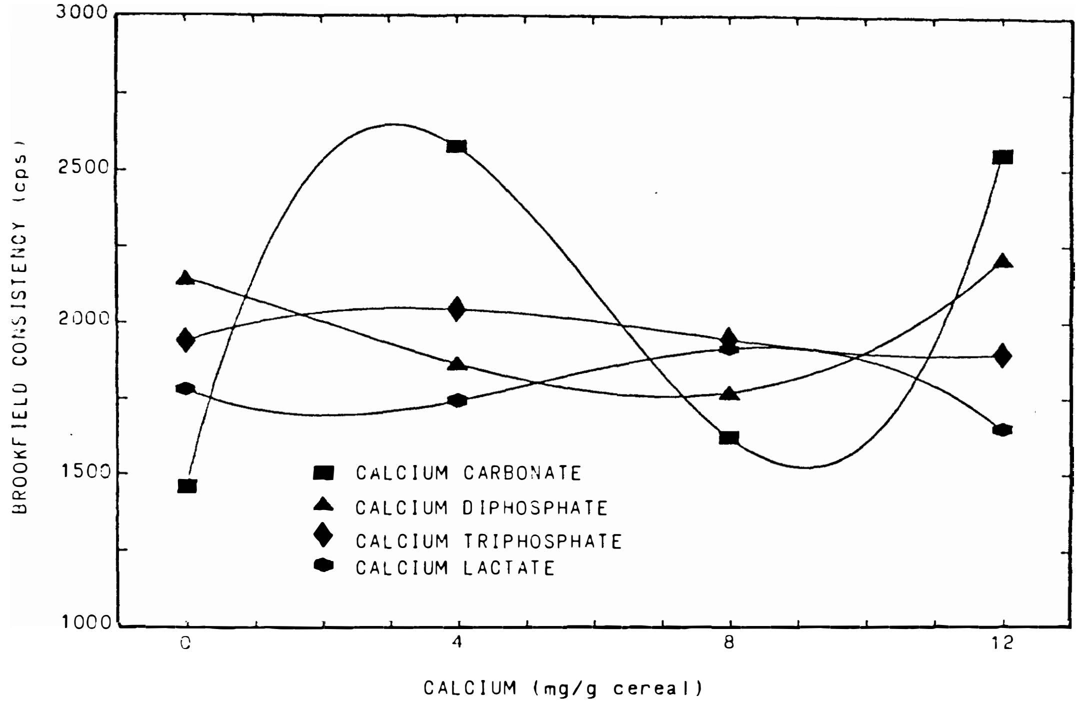

Fig. 23--Brookfield consistency of cooked corn-Ardex 700F gruels as affected by type of calcium salt and level of calcium.

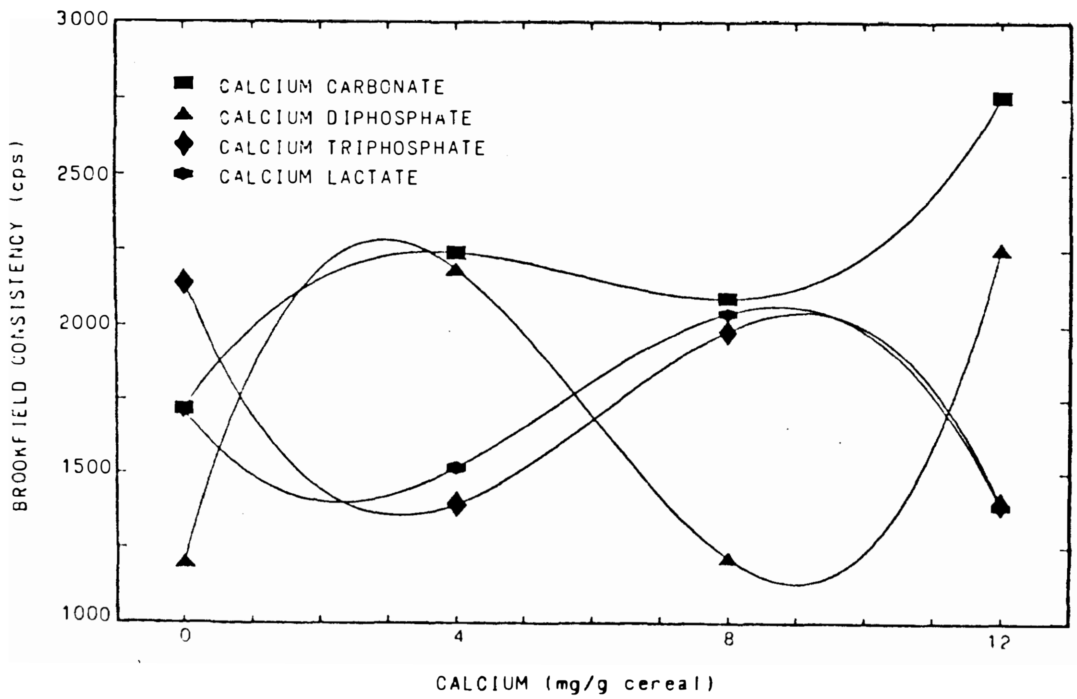

Fig. 24--Brookfield consistency of cooked corn-Ardex 700G gruels as affected by type of calcium salt and level of calcium.

of the cooked gruel in the food system. Concentrates absorbed the most water in the presence of calcium carbonate and calcium phosphate tribasic and were most viscous in the presence of calcium phosphate tribasic. Cereals containing calcium carbonate absorbed the most water and were the most viscous when cooked and measured with the Brookfield viscometer. Calcium lactate had the same effect in both systems; less water was absorbed and systems were the least viscous in the presence of this salt.

Even though temperature was not a variable studied in the food system, cooking the cereal for 2 min in boiling water as opposed to just heating it to 50°C did influence the effect of concentrate. The cereal containing powder concentrate was more viscous than the cereal containing grit concentrate, whereas the reverse held true for both the model system and the uncooked food system.

All other variables studied had no significant effects on the properties studied in the food system, even though effects were evident in the model system. The presence of pregelatinized corn meal in the cereal may have masked possible effects of other variables and interactions in the food system.

Nutritional Evaluation

Diets containing all combinations of the 2 cereals as the source of 10% protein and the 4 calcium salts at a calcium level of 540 mg/100 g diet were fed to 8 groups of 10 rats for a period of 28 days to determine PER (AOAC, 1975) of the diets compared to a casein control diet fed to a group of 10 rats.

The concentrate-containing diets did differ significantly ($P<0.05$) in PER from the casein control diet. However, the type of soy concentrate and the calcium salt did not affect the PER of the diets. Average weight gain, average food consumption, and actual and adjusted PER for each diet group are shown in Table 24.

Table 24--Nutritive values[a] of cereals as affected by soy concentrate and calcium salt compared with casein

Dietary Protein	Calcium[b] Salt	Avg Wt Gain (g)	Avg Food Consumption (g)	PER[c]	Adjusted[d] PER
Casein	CO_3	185	671	2.75	(2.50)
Corn-Ardex 700F	CO_3	173	693	2.55	(2.32)
	P_2	175	690	2.58	(2.34)
	P_3	178	730	2.48	(2.25)
	L	166	667	2.54	(2.31)
Corn-Ardex 700G	CO_3	178	707	2.56	(2.33)
	P_2	164	679	2.46	(2.24)
	P_3	178	716	2.58	(2.34)
	L	163	663	2.49	(2.26)

[a]Values based on group (10 rats)/4 wk.

[b]Calcium salt: CO_3 - calcium carbonate; P_2 - calcium phosphate dibasic; P_3 - calcium phosphate tribasic; L - calcium lactate.

[c]PER = g wt gain/g protein intake.

[d]Adjusted to: casein = 2.50.

The adjusted PER averaged 2.30 for the rat groups fed diets containing the powder concentrate, Ardex 700F, and 2.29 for the rat

groups fed diets containing the grit concentrate, Ardex 700G. As with the Bostwick consistency values, these PER values indicate that the powder and grit concentrate were similar and, therefore, possibly could be used interchangeably in the formulation of the corn-soy cereal. These PER values also compare favorably with adjusted PER values of USDA's CSB, 2.2-2.3 (Senti, 1974). In addition, the values obtained in this study were somewhat higher than those reported for the Ardex concentrates alone, PER of 2.0 (Table 2, p. 25), indicating an improved protein quality with the combination of soy concentrate and corn meal, as expected.

Kjeldahl analysis was used to determine the protein content of the cereals and showed the corn-Ardex 700F cereal to average 23.9% protein (N x 6.25) and the corn-Ardex 700G cereal 23.3% protein. Therefore, the protein content exceeded the minimum requirement for the USDA's CSB, 16.7% and also the reported value of 18.1% (Lorenz, 1976).

Sensory Evaluation

Gruels prepared from cereals containing the powder concentrate, Ardex 700F, and a 540 mg level of calcium/100 g cereal (based on an infant's RDA) from each of the 4 calcium salts were evaluated by 2 separate consumer panels. Three adults who had infants ranging in age from 9 to 21 mo evaluated the texture of the gruels by the consumer texture profile technique (Szczesniak et al., 1975). These same adults prepared and fed the four gruels to their infants and evaluated their infants' apparent acceptance of the product. Results presented are based on a limited sample size; therefore, no tests of significance were applied and results are considered only for possible patterns.

Figure 25 shows the consumer texture profiles of the cereals as deviations from an ideal infant gruel (adjusted to zero) in the panelists' opinion. For individual parameters, the gruels containing calcium carbonate and calcium lactate tended to have more scores closer to the ideal product than did those containing the other salts (Figure 25). However, gruels containing calcium lactate were rated particularly bad in texture compared to other gruels. This gruel was indicated by panelists to have a strong or bitter flavor and it is possible that the panelists were rating acceptance as affected by flavor and not just texture for several of the characteristics listed. It is interesting that the panelists rated the gruel containing calcium carbonate somewhat more thin, less thick and less watery than gruels containing either of the phosphate salts; yet in objective food system measurements, this gruel was the most viscous. Gruel containing calcium lactate was rated as the most thin and least thick of the gruels in agreement with findings from objective measurements.

The adults' evaluation of their infants' apparent acceptance of the gruels was difficult. The 9-mo infant would not eat any of the cereals but the parent did not attribute this dislike to the gruel but indicated that the infant was already eating cold ready-to-eat breakfast cereals and was not eating anything that looks like infant food. The 21-mo infant tried all the cereals but did not appear to like any until regular infant cereal was added. The parent indicated that the gruels possibly were not readily acceptable because they were thinner than gruels normally fed to the infant. However, even after addition of regular cereal, this infant appeared not to like the cereal containing

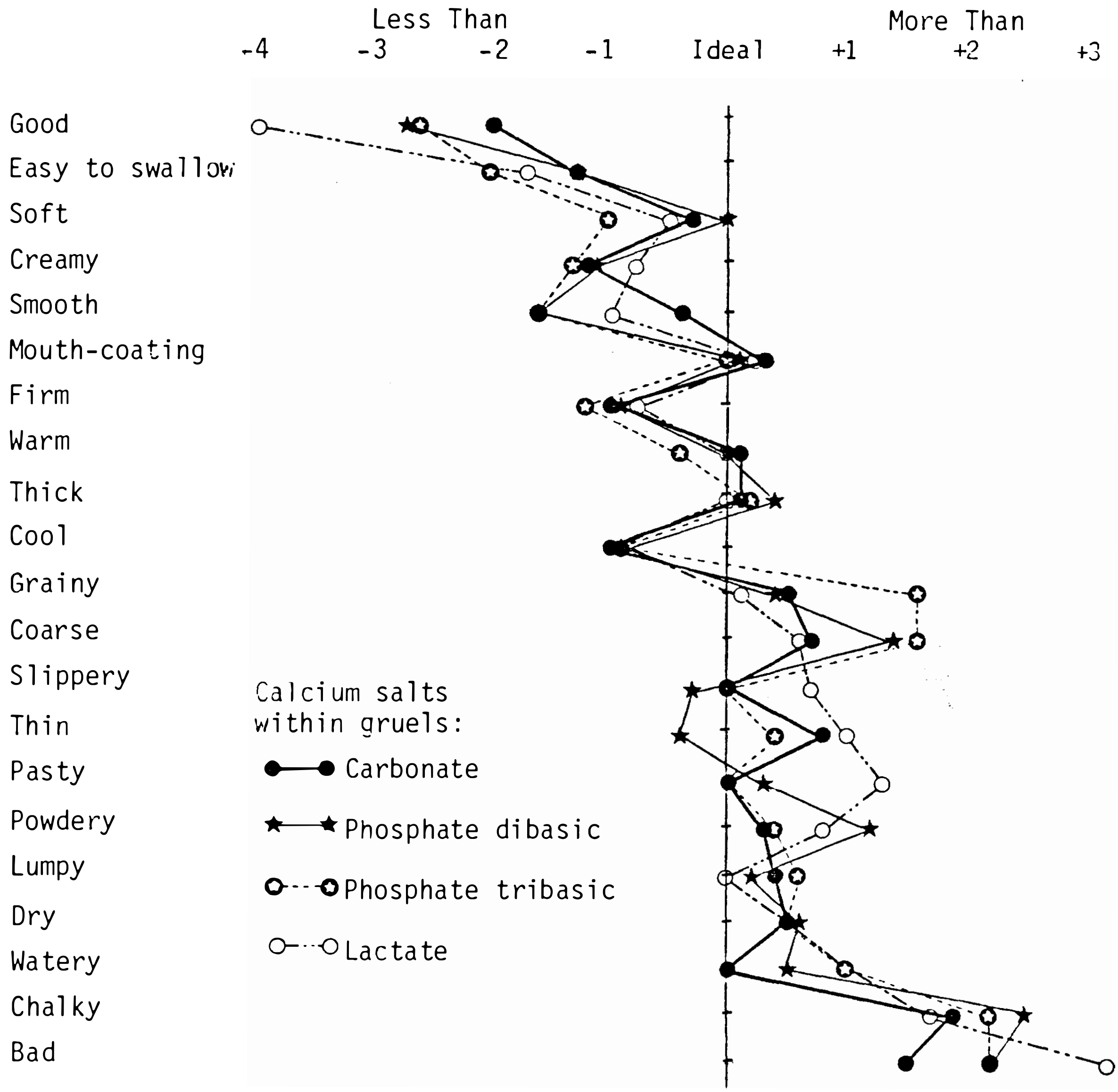

Fig. 25--Consumer texture profiles[a] of infant gruel, with results represented as deviations from the ideal product.

[a]Each point is an average for six evaluations (3 panelists x 2 replications).

calcium lactate. The 13-mo infant appeared to like both calcium phosphate-containing cereals as indicated by the eating of all of each gruel. The parent determined that the infant liked the calcium carbonate and calcium lactate-containing cereals only somewhat, since only half of each of these cereals was consumed. The parent noted that factors other than taste of the cereal might have been the reason. Overall, it is difficult to draw any conclusions because of the small number of infants participating in the evaluation and the fact that they received each cereal only once. Many external factors that may have influenced the infants' acceptance of the gruels were indicated by the parents and were difficult to separate from the actual acceptance of the cereal itself.

Limitations of the Study

Several limitations and problems encountered throughout the study that were not foreseen when the research was planned and proposed are listed below.

1. The quantities of calcium phosphate tribasic used throughout the study were slightly lower in calcium level than the other calcium salts as indicated in Table 4, footnote c, page 27.

2. The formulations for USDA's CSM and CSB have changed several times and the most recent formula was not acquired before calculating the amounts of the calcium salts needed for use in the model system. Therefore, the salt:soy ratios in the model system differed slightly from those that were used in the food system and presently suggested for use in USDA's CSB, as explained on page 34.

3. USDA specifications for Bostwick consistency for cooked CSB gruel are based on 11.75% suspensions, whereas 13% suspensions were used in this study inadvertently.

4. When the cereals were cooked for evaluation of Bostwick consistency in the manner specified by USDA, several of the cereal-calcium salt combinations developed an undesirable color (greenish-gray). Fortunately, the cereal is instant and does not require cooking before consumption. Adding the cereal to boiling water is sufficient preparation prior to consumption and does not result in any color change.

CHAPTER V

CONSIDERATIONS AND IMPLICATIONS

Methodology

Functional Measurements

Bressani (1969) discusses factors to be considered in the formulation and biological testing of food mixtures that are based on oilseed protein such as soy and designed for use as a weanling food and as a supplement to human diets. Most of the factors have been considered in this study.

Flow properties were measured with both the Brookfield viscometer and the Bostwick consistometer. It was evident that the Brookfield viscometer was more sensitive to changes attributable to the type of calcium salt used for fortification and may be most useful in research and development of a new product. The Bostwick consistometer is adequate and simpler for quality control use, since it is capable of detecting gross variations that may be due to product formulation differences. Both of these instruments give single-point measurements, which Rao (1977) suggested should be restricted to quality control work, since no meaningful information on flow behavior that is dependent on shear rate is obtained (Hermansson, 1975; Tung, 1978).

This study dealt mainly with the technological considerations of a food formulated with the use of soy protein. However, this protein component is not the only consideration necessary in the selected food system. Other added ingredients affected the functional properties studied. Corn meal affected physical properties of the food system,

possibly masking effects of the variables. The testing of corn meal in a model system containing the calcium salts but not the soy protein concentrates might have offered further explanation of effects that were observed. Also, the various calcium salts studied affected functional and sensory properties of the gruel in different ways. Therefore, the selection of calcium salt and possibly other added nutrients that are appropriate for the product is another important technological consideration when fortifying foods.

Nutritional Evaluation

The analytical framework for assessing feasibility, usefulness and success of fortification interventions is discussed in depth by Austin (1979). In one study no benefits were found for vitamin and mineral fortification, but the investigator emphasized that few nutritional interventions, by themselves, have been demonstrated in the field to have the expected nutritional benefits (Jansen, 1979) because of so many other intervening factors. Problems of protein malnutrition or even general undernutrition for many developing countries will not be solved all at once or by any one procedure or food; but a fortified cereal-protein mixture such as CSB is one possible option to consider for improving protein quality of diets. With improved protein quality, the quality of human resources in a country might improve, providing aid to national development in the long run. Altschul (1969) illustrates the possible impact of food aid and subsequent improved nutrition on an economy as shown in Figure 26.

The presence of phytates in soy did not appear to affect the nutritional quality of the cereal, as evidenced by the high PER values.

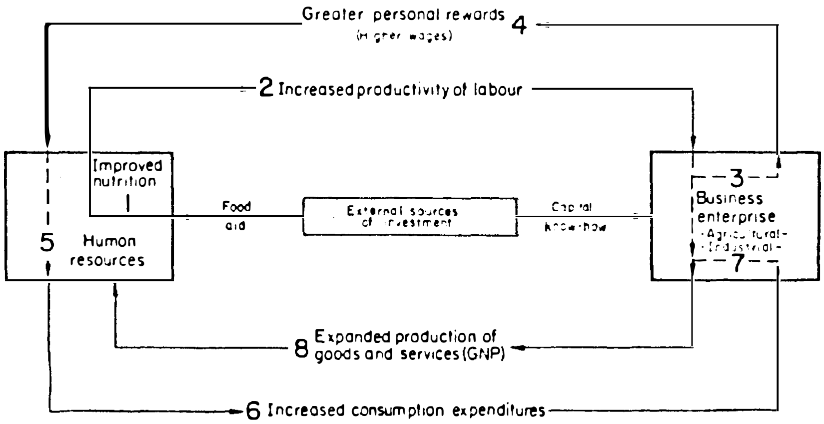

Fig. 26--The impact of food aid and improved nutrition on an economy (Altschul, 1969).

However, to adequately measure the influence of soy phytate on the bioavailability of calcium or other minerals, a method that involves rat diets containing incremental levels of the mineral being analyzed, such as the slope-ratio assay, is needed.

It would be desirable to test the nutritional value of the cereal of this study with infant biological testing to determine whether the concentrate product is superior to CSB because it contains more protein and less flatulence-producing carbohydrate.

Sensory Evaluation

Infants are a difficult group to work with in evaluating a product since there are many external factors that affect their food acceptance and are noncontrollable in a testing situation. Among the factors affecting their acceptance of a corn-soy cereal, in particular, is the unavailability of corn-based infant cereals; thus American infants are unfamiliar with them. It would be desirable to evaluate consumer sensory

acceptability of this product with infants who already consume CSB to determine whether the concentrate-containing cereal is more acceptable because concentrate is more bland in flavor than is soy flour.

Implementation

Considerations

Functional, nutritional and sensory properties are not the only considerations necessary for effective implementation and use of a new or improved food mixture. Austin (1979) discussed in depth the possible barriers to effective implementation of cereal fortification that would be applicable to the corn-soy cereal of this study. As with any intervention, Austin (1979) states that the starting point should be a thorough diagnosis of the whole food and nutrition system and problems of the area and people concerned. The structures of the commodity, administrative and organizational systems need to be examined and appropriate personnel consulted. Even if all of the above conditions suggest feasibility of implementation, the use of the product could falter if it is not acceptable to the consumer--organoleptically, culturally and economically. Intervention and program costs also need to be considered. Fortunately, USDA's CSB had already passed the tests and overcome the barriers for implementation and use in many developing countries and the corn-soy concentrate cereal could easily by-pass these barriers.

Uses

CSB is presently formulated with soy flour. Consistency and PER of the corn-soy cereals containing concentrates in this study were similar

to the specifications for USDA's CSB, suggesting the feasibility of replacing the soy flour, on an equal weight basis, with soy protein concentrate, a more concentrated source of protein. In addition, the powder and grit concentrate-containing cereals studied were similar in Bostwick consistency and PER values and could therefore be used interchangeably in the corn-soy concentrate cereal. Perhaps the powder concentrate-containing cereal could be used for feeding weanling infants and the grit concentrate-containing cereal could be used for feeding older infants and children.

The processing of the cereal within developing countries does not appear feasible nor practical since the recent introduction of low-cost extrusion cookers to developing countries. This technology involves adding corn grain and soybean to the extrusion cooker to produce an instant blend (Wilson and Stumpf, 1976). Therefore, the donation of CSB may discontinue in time as countries begin developing their own products with the use and introduction of extrusion cookers. However, as long as CSB continues to be used as a food commodity, the substitution of soy concentrate for soy flour should be considered. In addition, the possibility of substituting soy concentrate for soy flour in United States marketed infant foods should be considered.

CHAPTER VI

SUMMARY

The substitution of soy protein concentrates for soy flour in a USDA food commodity, corn-soy blend, and fortification with four calcium salts—calcium carbonate, calcium phosphate di- and tribasic, and calcium lactate—were investigated. A model system was used in a systematic investigation of water absorption and Brookfield consistency of four soy concentrates, two powder—Promosoy-100 and Ardex 700F—and two grit—Promosy 20/60 and Ardex 700G. Each concentrate was evaluated with the 4 calcium salts at calcium levels of 0, 400, 800 and 1200 mg/23.4 g concentrate and at ambient temperature (22-25°C) and 50°C. The food system, a corn-soy cereal was subjected to evaluation of the functional, nutritional and sensory characteristics. Cereals containing Ardex 700F and Ardex 700G with the 4 calcium salts at calcium levels of 0, 400, 800 and 1200 mg/100 g cereal were evaluated at 50°C for the functional properties of water absorption and Brookfield consistency and also were evaluated for Bostwick and Brookfield consistency after cooking and cooling to 30°C. The findings for the model system were related to those involving functional properties for the food system to evaluate the degree to which the model system measurements could predict functional performance of the soy protein concentrates in the corn-soy cereal. Both cereals containing all 4 calcium salts at a calcium level of 540 mg/100 g diet were evaluated for nutritional quality by PER. Gruels containing the powder concentrate, Ardex 700F, and the 4 calcium

salts at a calcium level of 540 mg/100 g cereal were evaluated for texture characteristics by adults, who also assessed the gruels' apparent acceptability when fed to infants.

Water absorption and Brookfield consistency were affected by the soy concentrate, temperature, calcium salt, level of calcium and the second order interactions in the model system. In the uncooked food system, water absorption and Brookfield consistency were affected by the soy concentrate, but only water absorption was affected by the calcium salts. The effects of concentrate were similar in the model system and the uncooked food system. Grit concentrates and the cereal containing grit concentrate absorbed more water and had greater suspension consistency than counterpart powder concentrates and cereal containing powder concentrate. Water absorption and Brookfield consistency of the model system were greater at 50°C than at ambient temperature (unexplained exception: the Ardex 700F suspensions were less viscous at 50°C than at ambient temperature). Temperature was not a variable studied in the food system. However, cooking the cereal, as opposed to just heating it, resulted in a reversal of the apparent effect of concentrate; in the cooked system the cereal containing powder concentrate was more viscous than the cereal containing grit concentrate.

Calcium salts had a significant effect on both water absorption and Brookfield consistency of the model system, whereas this effect was evident only for water absorption and Brookfield consistency measurement of the cooked gruel in the food system. Concentrates tended to absorb the most water in the presence of calcium carbonate and calcium phosphate tribasic and their suspensions were most viscous in the presence of

calcium phosphate tribasic. Cereals containing calcium carbonate absorbed the most water and were the most viscous when cooked and measured with the Brookfield viscometer. Calcium lactate had the same effect in both systems; the least water was absorbed and systems were the least viscous in the presence of this salt.

The level of calcium had an effect in the model system but no significant effect was evident in the food system. Overall, the increasing level of calcium had a decreasing effect on water absorption and suspension consistency of the model system; however, other variables affected the response to salt level considerably.

In the model system, numerous interactions observed indicate that the relationships among the variables studied are complex. The possible effects of the variables and interactions in the food system possibly were masked by the presence of pregelatinized corn meal in the cereal.

Nutritional quality of the cereals was not affected by soy concentrate or by calcium salt. All soy concentrate-calcium salt diet combinations resulted in PER values of 2.24-2.34 (based on 2.5 for casein). Sensory properties of the gruel containing the powder concentrate were somewhat affected by calcium salt. The gruel containing calcium lactate was rated as the most thin and least thick of the gruels in agreement with objective measurements. This gruel also was indicated by the adult panelists to have a strong or bitter flavor. However, this gruel and that containing calcium carbonate tended to be scored closer in texture characteristics to an ideal product than those containing the phosphate salts. It was difficult to draw any conclusions about the infants' apparent acceptance of the gruels since very few infants were

used and they were given each gruel only once. Their acceptance probably was influenced by external factors.

Implementation and use of the corn-soy concentrate cereal involves many considerations, but it appears feasible and advantageous to substitute soy concentrate for soy flour in CSB. In the formulation and fortification of such blends, the calcium salt selected for fortification needs to be considered because the form of calcium may affect the final food product.

LIST OF REFERENCES

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APPENDIXES

APPENDIX A

Table A-1--Example of randomized order used in data collection for model system[a]

Soy	°C	Bl	Rep[b]	Calcium Salt[c]-Calcium Level (mg/0.234 g concentrate)							
PG	50	1	1	C 8	D 8	T 4	D 0	T12	C 0	L 4	L12
PG	am	2	1	T 4	T 8	C12	D12	C 4	L 8	L 0	T 0
AG	50	2	1	T 4	T12	C 4	L 0	T 0	L 8	C12	T 8
AG	am	1	1	L 4	D 8	C 8	C 0	T12	L12	T 4	D 0
AG	am	1	2	T 8	L 4	D 0	T 4	C 8	C 0	T12	L12
AP	am	1	1	T12	D 8	L 4	T 4	C 0	C 8	L12	D 0
AP	am	2	1	L 0	D 4	T 0	C12	T 8	D12	L 8	C 4
AP	50	2	1	D 4	D12	T 0	T 8	C12	L 0	C 4	L 8
PP	50	1	1	D 8	T 4	D 0	C 8	C 0	T12	L 4	L12
AP	am	1	2	C 0	L12	D 8	T 4	T12	D 0	C 8	L 4
AG	am	2	1	L 8	T 0	C12	T12	D 4	L 0	T 8	C 4
AG	50	1	1	D 0	T12	C 8	T 4	L 4	L12	C 0	D 8
PG	am	2	2	T 8	L 8	C 4	L 0	D12	T 0	D 4	C12
PG	am	1	1	C 0	D 8	T 4	T12	C 8	L 4	L12	D 0
AP	50	1	1	L12	C 0	L 4	D 0	T12	T 4	C 8	D 8
PP	50	2	1	D12	L 0	T 8	C12	C 4	D 4	T 0	L 8
PG	50	1	2	T12	C 0	T 4	C 8	L12	D 8	D 0	L 4
PP	am	1	1	D 8	C 8	T12	C 0	T 4	D 0	L12	L 4
PP	50	1	2	D 0	C 8	T12	L12	C 0	D 8	T 4	L 4
AP	50	2	2	C 4	T 0	C12	L 0	T 8	D 4	L 8	D12
AP	am	2	2	L 0	T 8	C 4	D 4	D12	C12	T 0	L 8
PG	am	1	2	L 4	T 4	L12	C 8	D 0	T12	D 8	C 0
AG	50	1	2	C 0	T12	L12	T 4	C 8	D 0	D 8	L 4
AP	50	1	2	L 4	T 4	D 0	C 8	T12	D 8	L12	C 0
PG	50	2	1	T 8	D12	C 4	L 0	D 4	T 0	C12	L 8
AG	am	2	2	D12	C 4	C12	T 8	L 8	L 0	D 4	T 0
PP	50	2	2	C 4	C12	L 8	D12	L 0	T 0	D 4	T 8
PG	50	2	2	L 8	L 0	D12	T 8	T 0	C 4	D 4	C12
PP	am	1	2	L12	T 4	T12	C 0	D 8	L 4	D 0	C 8
PP	am	2	1	T 8	D12	C 4	T 0	D 4	L 0	C12	L 8
AG	50	2	2	C12	L 8	D12	T 0	D 4	L 0	C 4	T 8
PP	am	2	2	L 0	C12	T 0	D12	D 4	L 8	C 4	T 8

[a]Separate randomization done for each measurement.

[b]Soy: PP - Promosoy-100, PG - Promosoy 20/60, AP - Ardex 700F, AG - Ardex 700G; C: am - ambient; Bl: block; Rep: replication.

[c]Calcium salt: C - calcium carbonate, D - calcium phosphate dibasic, T - calcium phosphate tribasic, L - calcium lactate.

Table A-2--Analyses of protein sources used in rat diets (as-is basis)

Protein Source	Protein[a]	Moisture[a]	Fat[b]	Crude Fiber[b]	Ash[b]
	%				
Casein	93.18	9.02	0.01	-	2.3
Ardex 700F	70.24	5.68	1.5	3.7	4.5
Ardex 700G	70.19	8.92	1.5	3.7	4.5
Corn meal	10.00	9.56	2.2	2.8	1.4

[a]Investigator's analyses. Protein = N x 6.38 for casein and N x 6.25 for the other sources.

[b]Suppliers' analyses.

Table A-3--Water absorption[a] of the Promosoy concentrates at ambient temperature and 50°C as affected by type of calcium salt and level of calcium

	Calcium Salt[b]	Calcium Level (mg/0.234 g concentrate)				
		0	4	8	12	Mean
		%				
Promosoy-100 ambient	CO_3	279.8	267.7	263.6	254.3	266.3
	P_2	278.7	254.4	234.6	224.2	248.0
	P_3	276.0	271.1	257.9	254.5	264.9
	L	277.8	221.1	204.7	196.3	225.0
	Mean	278.1	253.6	240.2	232.3	
50°C	CO_3	314.1	321.6	302.8	306.3	311.2
	P_2	309.2	298.6	259.3	261.2	282.1
	P_3	328.8	302.9	308.2	281.7	305.4
	L	327.7	232.8	234.1	211.5	251.5
	Mean	320.0	289.0	276.1	265.2	
Promosoy 20/60 ambient	CO_3	366.2	343.9	340.1	324.0	343.6
	P_2	369.8	330.2	312.0	288.0	325.0
	P_3	354.1	354.5	331.0	327.8	341.9
	L	354.8	287.3	260.2	246.1	287.1
	Mean	361.2	329.0	310.8	296.5	
50°C	CO_3	427.5	389.3	390.1	360.1	391.8
	P_2	425.9	368.7	359.7	325.3	369.9
	P_3	407.2	406.7	373.8	376.3	391.0
	L	403.8	335.0	286.2	278.9	326.0
	Mean	416.1	374.9	352.4	335.2	

[a]Each value is an average for two replications. Values have been adjusted for effect of block.

[b]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

Table A-4--Water absorption[a] of the Ardex concentrates at ambient temperature and 50°C as affected by type of calcium salt and level of calcium

	Calcium[b] Salt	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
		%				
Ardex 700F ambient	CO_3	295.9	314.4	309.5	292.5	303.1
	P_2	296.3	300.5	259.5	258.1	278.6
	P_3	297.5	323.8	305.3	295.9	305.6
	L	297.8	282.9	260.8	244.8	271.6
	Mean	296.9	305.4	283.8	272.8	
50°C	CO_3	354.6	317.2	320.2	312.0	326.0
	P_2	353.6	297.0	290.3	272.9	303.4
	P_3	358.8	333.2	318.8	312.2	330.8
	L	346.0	282.7	267.6	242.0	284.6
	Mean	353.3	307.5	299.2	284.8	
Ardex 700G ambient	CO_3	383.5	348.5	333.8	329.6	348.8
	P_2	381.8	342.1	316.2	298.9	334.8
	P_3	380.1	370.6	351.0	338.4	360.0
	L	378.7	317.0	291.2	272.0	314.7
	Mean	381.0	344.5	323.0	309.7	
50°C	CO_3	385.7	369.6	337.2	343.7	359.0
	P_2	385.6	351.1	319.2	317.7	343.4
	P_3	401.0	373.3	370.2	339.2	370.9
	L	397.3	334.4	302.4	270.2	326.1
	Mean	392.4	357.1	332.2	317.7	

[a]Each value is an average for two replications. Values have been adjusted for effect of block.

[b]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

Table A-5--Brookfield consistency[a] of the Promosoy concentrates at ambient temperature and 50°C as affected by type of calcium salt and level of calcium

	Calcium[b] Salt	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
		cps				
Promosoy-100 ambient	CO_3	38.2	47.3	43.7	55.3	46.1
	P_2	36.7	41.3	32.2	45.3	38.9
	P_3	39.8	40.7	50.8	56.2	46.9
	L	40.8	20.7	26.3	20.7	27.1
	Mean	38.9	37.5	38.2	44.4	
50°C	CO_3	47.7	63.3	79.2	84.8	68.8
	P_2	48.2	47.3	49.2	53.3	49.5
	P_3	48.3	51.2	58.8	68.2	56.6
	L	47.8	29.7	26.3	25.7	32.4
	Mean	48.0	47.9	53.4	58.0	
Promosoy 20/60 ambient	CO_3	617.4	544.1	455.9	383.6	500.2
	P_2	541.9	547.1	523.4	525.6	534.5
	P_3	516.1	466.4	370.1	326.9	419.9
	L	558.1	545.4	409.1	282.9	448.9
	Mean	558.4	525.8	439.6	379.8	
50°C	CO_3	844.7	869.8	772.2	568.8	763.9
	P_2	1000.7	839.3	743.2	624.8	802.0
	P_3	826.8	748.2	650.3	537.2	690.6
	L	887.8	578.2	532.8	523.7	630.6
	Mean	890.0	758.9	674.6	563.6	

[a]Each value is an average for 12 measurements (2 replications x 3 subsamples x 2 readings). Values have been adjusted for effect of block.

[b]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

Table A-6--Brookfield consistency[a] of the Ardex concentrates at ambient temperature and 50°C as affected by type of calcium salt and level of calcium

	Calcium[b] Salt	Calcium Level (mg/0.234 g concentrate) 0	4	8	12	Mean
		------------------- cps	-------------------			
Ardex 700F ambient	CO_3	257.6	253.4	259.6	256.4	256.8
	P_2	265.1	240.4	247.1	243.4	249.0
	P_3	259.9	270.6	276.4	295.6	275.6
	L	254.9	160.6	168.9	231.1	203.9
	Mean	259.4	231.2	238.0	256.6	
50°C	CO_3	231.0	204.0	230.5	221.5	221.8
	P_2	236.0	189.5	192.0	201.5	204.8
	P_3	225.0	241.5	244.0	254.5	241.2
	L	233.0	132.0	138.0	145.5	162.1
	Mean	231.2	191.8	201.1	205.8	
Ardex 700G ambient	CO_3	446.2	314.3	323.2	285.3	342.2
	P_2	455.2	284.3	276.7	249.8	316.5
	P_3	395.8	458.7	396.3	595.2	461.5
	L	389.8	157.7	164.8	171.7	221.0
	Mean	421.8	303.8	290.2	325.5	
50°C	CO_3	710.2	399.8	516.2	443.8	517.5
	P_2	674.2	318.3	389.2	269.8	412.9
	P_3	618.3	717.2	541.8	741.7	654.8
	L	508.3	213.2	128.8	200.7	262.8
	Mean	627.8	412.1	394.0	414.0	

[a]Each value is an average for 12 measurements (2 replications x 3 subsamples x 2 readings). Values have been adjusted for effect of block.

[b]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

Table A-7--Water absorption[a] of cereals and Brookfield consistency[b] of cereal suspensions containing Ardex 700F or 700G as affected by type of calcium salt and level of calcium

	Calcium Salt[c]	Calcium Level (mg/g cereal) 0	4	8	12	Mean
		%				
Water Absorption Ardex 700F	CO_3	197.7	198.9	195.4	195.6	196.9
	P_2	196.8	196.8	186.0	189.0	192.2
	P_3	200.9	194.4	195.4	191.6	195.6
	L	201.9	183.2	183.9	179.1	187.0
	Mean	199.3	193.4	190.2	188.8	
Ardex 700G	CO_3	196.4	226.8	210.6	213.2	211.8
	P_2	195.9	191.4	214.3	204.2	201.4
	P_3	194.6	222.0	190.2	191.6	199.6
	L	203.3	184.4	182.2	177.5	186.8
	Mean	197.6	206.2	199.3	196.6	
		cps				
Brookfield Consistency Ardex 700F	CO_3	106.3	108.7	87.3	108.2	102.6
	P_2	102.3	111.2	103.8	110.2	106.9
	P_3	112.7	101.8	109.7	104.3	107.1
	L	110.2	107.3	112.7	101.8	108.0
	Mean	107.9	107.2	103.4	106.1	
Ardex 700G	CO_3	122.4	126.1	124.9	141.6	128.8
	P_2	120.9	127.6	118.9	126.1	123.4
	P_3	116.1	123.3	129.6	131.9	125.2
	L	125.1	130.3	127.6	123.4	126.6
	Mean	121.1	126.9	125.2	130.8	

[a]Each value is an average for 2 replications. Values have been adjusted for effect of block.

[b]Each value is an average for 12 measurements (2 replications x 3 subsamples x 2 readings). Values have been adjusted for effect of block.

[c]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

Table A-8--Bostwick and Brookfield consistency[a] of cooked gruels containing Ardex 700F or 700G as affected by type of calcium salt and level of calcium

	Calcium Salt[b]	Calcium Level (mg/g cereal)				
		0	4	8	12	Mean
		cm/min				
Bostwick Consistency Ardex 700F	CO_3	16.4	14.2	17.6	13.8	15.5
	P_2	14.8	15.2	15.4	14.4	15.0
	P_3	15.2	15.0	15.0	15.0	15.0
	L	16.1	16.2	16.0	16.2	16.1
	Mean	15.6	15.2	16.0	14.8	
Ardex 700G	CO_3	16.6	15.2	15.7	14.2	15.4
	P_2	17.2	15.2	17.7	14.6	16.2
	P_3	15.6	17.0	15.5	16.4	16.1
	L	16.5	17.1	15.3	17.3	16.6
	Mean	16.5	16.1	16.0	15.6	
		cps				
Brookfield Consistency Ardex 700F	CO_3	1458.4	2579.6	1624.4	2549.6	2053.0
	P_2	2148.4	1865.6	1772.4	2211.6	1999.5
	P_3	1939.6	2046.4	1947.6	1896.4	1957.5
	L	1779.6	1744.4	1917.6	1652.4	1773.5
	Mean	1831.5	2059.0	1815.5	2077.5	
Ardex 700G	CO_3	1718.2	2241.8	2094.2	2757.8	2203.0
	P_2	1200.2	2189.8	1212.8	2255.8	1714.6
	P_3	2143.8	1396.2	1983.8	1400.2	1731.0
	L	1709.8	1518.2	2043.8	1390.2	1665.5
	Mean	1693.0	1836.5	1833.6	1951.0	

[a]Each value is an average for two replications. Values have been adjusted for effect of block.

[b]Calcium salt: CO_3 - calcium carbonate, P_2 - calcium phosphate dibasic, P_3 - calcium phosphate tribasic, L - calcium lactate.

APPENDIX B

"IDEAL" Texture of Baby Cereal

Before actual testing of the baby cereal, I am interested in how you would describe the textural characteristics of an "ideal baby cereal." You are provided with a sheet consisting of a list of terms commonly used to describe texture, i.e., how foods feel in the mouth. Using these terms, please check one of the six boxes along the side of each term to indicate the degree to which you feel an ideal baby cereal should have the textural characteristics described by that term. It is important to the test that you make a choice for each term.

Procedure for Evaluating Baby Cereal

Please read these instructions carefully before starting:

You are being provided with 4 score sheets, one for each baby cereal that will be presented to you (one at a time). Again, each sheet consists of the same list of terms commonly used to describe texture, i.e., how foods feel in the mouth. Using these terms, describe the texture of each sample as it is presented to you. To do this, please check one of the six boxes along the side of each term to indicate the degree to which you feel this sample has the textural characteristic described by that term. It is important to the test that you make a choice for each term.

Please stir each sample before testing and take a drink of water between samples.

Raise hand (or ask) if you need more water or other assistance.

TEXTURE of Baby Cereal

Code___________

Date___________

Sample _________

	Not At All					Very Much So
Grainy	☐	☐	☐	☐	☐	☐
Easy to Swallow	☐	☐	☐	☐	☐	☐
Pasty	☐	☐	☐	☐	☐	☐
Bad	☐	☐	☐	☐	☐	☐
Coarse	☐	☐	☐	☐	☐	☐
Good	☐	☐	☐	☐	☐	☐
Smooth	☐	☐	☐	☐	☐	☐
Slippery	☐	☐	☐	☐	☐	☐
Thin	☐	☐	☐	☐	☐	☐
Cool	☐	☐	☐	☐	☐	☐
Powdery	☐	☐	☐	☐	☐	☐
Lumpy	☐	☐	☐	☐	☐	☐
Creamy	☐	☐	☐	☐	☐	☐
Mouth-coating	☐	☐	☐	☐	☐	☐
Firm	☐	☐	☐	☐	☐	☐
Chalky	☐	☐	☐	☐	☐	☐
Watery	☐	☐	☐	☐	☐	☐
Warm	☐	☐	☐	☐	☐	☐
Dry	☐	☐	☐	☐	☐	☐
Thick	☐	☐	☐	☐	☐	☐
Soft	☐	☐	☐	☐	☐	☐

Procedure for Infant Evaluation of Baby Food Cereal

Please store the individual cereal packages in the refrigerator before use. Within the next 2-3 weeks, prepare each of the four cereals at separate times, during the same time of day and in the same manner you prepare any commercial baby food cereal. Allow at least 2 days between cereal preparations and presentations to the infant and use only one package in any one day. Use the following order in preparing and presenting the cereals: ___, ___, ___, ___ (codes).

Prepare the cereal as stated below and answer the following questions for each cereal (unless otherwise stated) as it is fed to the infant. Do not force feed this cereal to the infant. However, allow him/her to take at least 2-4 spoonfuls without adding anything else to the cereal. Then you may add other ingredients or feed the infant his/her regular cereal. If at any time you encounter any problems or have any questions, please do not hestitate to call Charlene James at 974-3491 (school) or 523-2759 (home).

Thank you for your assistance in this research project.

Code _____ Sample _________

Preparation:

1. Place 1/4 measured cup of boiling water into a commonly used "cereal bowl."
2. Add _________ cereal slowly to the water.
3. Stir the cereal constantly during the addition. Small lumps may be eliminated by additional stirring.
4. Serve warm to your infant without adding any other ingredients, at least not before the infant has tasted 2-4 spoonfuls.
5. Answer the following questions.

Score Card

Date __________ Time __________ Infant's age in months _____ Infant's sex ___

Does the infant appear to like the cereal? (circle one) YES NO SOMEWHAT

How can you tell? ____

____

How much cereal did the infant eat? (circle one)

ALL MORE THAN HALF HALF LESS THAN HALF NONE

If he/she appeared to not like the cereal, what might you do to improve it? (such as adding sugar, salt, adding more or less water, heating longer, etc.)

____

Did you add anything to the cereal after the first 2-4 spoonfuls? YES NO
If YES, what did you add? (such as sugar or salt, fruit, milk, etc.) __________

____

Please answer the following questions only once.

What commercial cereal do you most often feed the infant? ____________________

How often, in a week do you feed your infant cooked cereal? (circle one)

2-3 TIMES OR MORE ONCE LESS THAN ONCE

Do you add anything to other cooked cereals that you feed the infant? YES NO
If YES, what do you add? (such as sugar, salt, milk formula, fruit, etc). ______

____

Additional Comments:

VITA

The author was born in Maple Shade, New Jersey, on May 19, 1954. In 1972 she graduated from Merchantville High School, Merchantville, New Jersey. After working for a year and attending several night classes at Burlington County College, the author attended Glassboro State College in the fall of 1973. The following June, 1974, the author married John Hoffmeister and moved to Glassboro, New Jersey, where from 1975 to 1978 the couple jointly held an appointment as resident director of Hollybush, a National Historical monument on the campus. In December 1976, the author completed her undergraduate studies and graduated summa cum laude with the Bachelor of Arts degree in Home Economics Education and collateral areas in journalism and science. After working as a Home Economist for several months in Philadelphia, the author accepted a graduate research assistantship at The University of Tennessee, Knoxville, in September 1977 and pursued the Doctor of Philosophy degree with a major in Food Science and collateral areas in Nutrition and Rural Sociology.

She is a member of Phi Tau Sigma, Phi Kappa Phi, Omicron Nu, the American Home Economics Association, the International Federation of Home Economists, the Institute of Food Technologists and the American Oil Chemists' Society.

The author is the daughter of the late Charles H. James, Sr. and Angelina Gambino James of Clearwater, Florida.