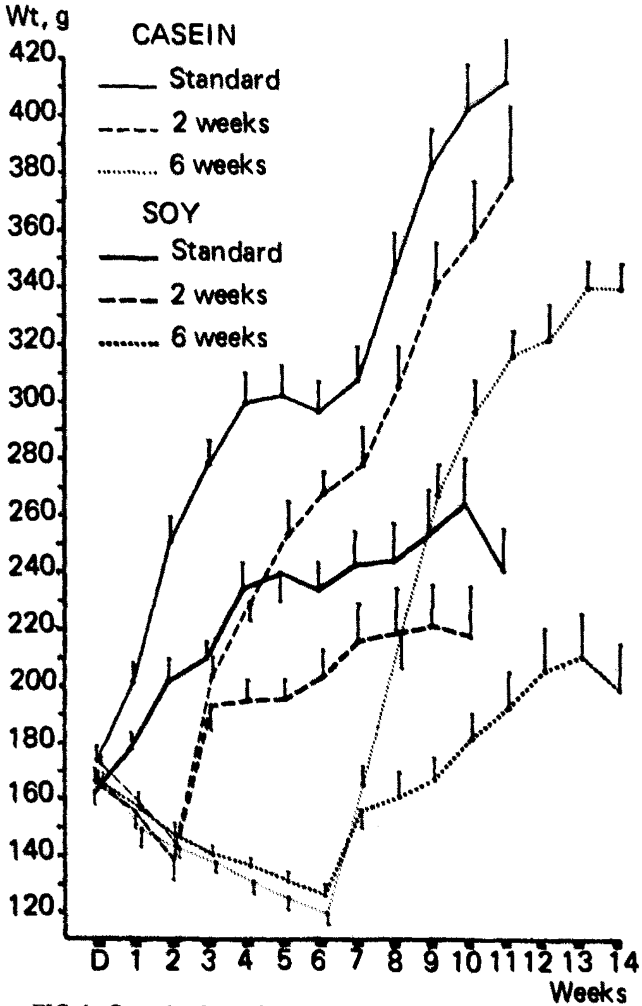

FIG. 1. Growth of rats fed casein or soy protein diets with and without previous protein free diets for 14 or 42 days.

institution. First group, 11 children, average age, 33 months; second group, 12 children, average age, 48 months.

Textured soy protein: We used soy proteins with ham flavor, with beef flavor, and with no flavor. The children's daily diets contained 18 g dried textured soy protein (20% total daily protein).

Diets: Four kinds of diets were used successively: fixed normal diet without soy proteins for 1 week, fixed diet containing soy proteins for 1 week, ad libitum diet without soy proteins for 1 week, and ad libitum diet containing soy proteins for 1 week.

Results

The results of the first and second groups are given successively in Tables I and II. It is obvious that there were no significant differences between food intakes during the weeks of fixed diets and those of the ad libitum diets with or without soy protein. Results of the two groups of children were also close.

COMPARATIVE NITROGEN BALANCE OF ADULTS FED BOTH A NORMAL DIET AND A DIET CONTAINING SOY PROTEIN FOR ONE WEEK EACH

Protocol

Subjects: Ten normal subjects from 43-79 years of age participated.

Diet: In the first week, the subjects received a normal diet. In the second week, meat protein was replaced by an equal amount of textured soy protein. The average composition of the diets was: animal protein, 29%; vegetable protein, 37%; and soy protein, 23%.

Results

Results of the nitrogen balance tests are given in Table III. There was no significant difference of CDU, net protein utilization (NPU), and biological value (BV) between the two kinds of diets.

COMPARISON BETWEEN THE EFFICACY OF CASEIN AND THE EFFICACY OF TEXTURED PROTEIN ON THE NUTRITIONAL RECUPERATION OF RATS FED A PROTEIN FREE DIET FOR 14 OR 42 DAYS

Protocol

For this experiment, 120 rats, each weighing 170 g were used. They were divided into six groups of 20 rats each. The first group was fed a casein diet all the time; the second group was fed a protein free diet for 14 days and then a casein diet. The third group was fed a protein free diet during 42 days and then a casein diet, while the fourth group was fed a soy protein diet all the time. The fifth group was fed a protein free diet for 14 days and then a soy protein diet, and the sixth group was fed a protein free diet for 42 days and then a soy protein diet.

Results

Figure 1 shows the growth of each group of rats. In the groups previously fed a protein free diet, the rats fed the soy proteins grew less than those fed casein. It is possible that the rats fed textured soy protein had a lower protein intake than those fed casein. It is difficult to calculate the exact quantity of daily intake because there were certain losses of soy proteins during feeding.

In general our studies on adults and children showed that the acceptability and digestive tolerance of textured soy proteins were fairly good. There was no significant difference in the nitrogen balance of adults when meat protein was replaced by textured soy protein. As for the study on the growth of rats, we should consider that the lower wt gain on the soy diet was probably the result of a lower intake of soy protein than of casein.

Nutritional Experience with Infant Formulas Containing Soy

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INTRODUCTION

Many of the developing nations have little in the way of an organized dairy industry. Often production of cows' milk is limited and spotty, the microbiological quality is generally poor, and satisfactory facilities for collecting, processing, and bottling milk may be virtually nonexistent. Under these conditions the need for infant and weaning foods at reasonable cost based on non-dairy ingredients is very great. The practice at weaning time often has been to offer the infant whatever food the grown-ups have available. As a result the infants fare poorly. Digestive disturbances and malnutrition are common and mortality is high.

Therefore it is not surprising that we in The League for International Food Education (LIFE) get many requests for technology for producing soy milk products ranging from

TABLE I

Examples of Commercially Prepared U.S. Formulas with Protein from Soy Isolate or Soy Flour[a]

Components	Soy isolate	Soy flour
Protein	Vegetable oils	Vegetable oils
Fat	Corn syrup solids and/or sucrose	Corn syrup solids and/or sucrose
Examples	Isomil (Ross) Neo-Mull-Soy (Syntex) ProSobee (Mead)	Sobee (Mead) Mull-Soy (Syntex)
Major constituents (gm/100 ml)		
Protein	2.0-2.5	3.1-3.2
Fat	3.4-3.6	2.6-3.6
Carbohydrate	6.8	5.2-7.7
Minerals	0.4-0.5	0.5-0.8
Caloric distribution (% calories)		
Protein	12-15	19
Fat	45-48	35-49
Carbohydrate	40	32-46
Content of minerals/liter		
Calcium (mg)	700-850	1060-1200
Phosphorus (mg)	500-630	530-800
Sodium (meq)	13-24	16-22
Potassium (meq)	18-28	33-41
Chloride (meq)	7-15	14-16
Magnesium (mg)	75-80-100	75
Copper (mg)	0.6	0.4
Iodine (μg)	70-160	60-160
Iron (mg)	8.5-12	5.0-8.5
Content of vitamins/liter		
Vitamin A (I.U.)	1500-1590	1590-2110
Thiamin (μg)	400-530	530
Riboflavin (μg)	600-1060	850-1060
Niacin (mg)	6.0-7.4	7.4-9.5
Pyridoxine (μg)	400-430	420-430
Pantothenate (mg)	2.6-5.0	1.0-2.6
Vitamin C (mg)	40-53	42-53
Vitamin D (I.U.)	400-	423
Vitamin E (I.U.)	5-11	5-11
Vitamin K (mg)	0.15	

[a]See ref. 2.

small scale village processing to larger more sophisticated operations. The appropriate organs of the United Nations as well as many institutions of developed countries have correctly emphasized the merits of oilseeds and especially soybeans as a major relatively low cost source of good quality protein. This has helped to awaken and maintain continuing interest in developing countries.

In the case of the developed countries, such as the U.S., infant formulas based on soy products largely have been used with infants who have not responded well to cows' milk or who have shown allergic reactions to milk.

DEVELOPMENT OF SOY-BASED INFANT FORMULAS

It has been estimated that in 1973 ca. 10% of infants in the U.S. will be fed formulas based on soy protein isolate (1). In the U.S. in the 1950's and 1960's, infant formulas based on soy flour as the protein source in place of milk proteins were developed and marketed. These were among the better milk substitutes. However, the formulas often produced loose, malodorous stools and caused chafing in the diaper area.

In the mid 1960's, water dispersible soy protein isolates became available. These permitted the formulation of infant foods white in color, nearly odorless, and seldom causing loose or malodorous stools. In the process for producing the soy protein isolate, it became possible to remove indigestible or irritating components. In the 1970's, formulas based on soy protein isolate have largely replaced the soy flour formulas. Examples of the two types of formulations are shown in Table I (2).

PROBLEMS WITH SOY-BASED FORMULAS AND REMEDIAL MEASURES

Raw soybeans or soy flour contain the enzyme urease, a trypsin inhibitor, and hemagglutinins (3). These undesirable components are inactivated by suitable heat treatment. Excessive heat treatment, however, can reduce the availability of the amino acids in the soy protein. The protein quality index of soy protein can show considerable variation depending on processing variables, such as temperature and time. Raw soybeans or soy flour also contain a goitrogenic factor, which can be removed by solvent extraction or by heating. Supplementing the diet with iodine also overcomes the effect of this factor.

Solvent extraction of the fat from soy flour removes the fat soluble vitamins originally present, namely Vitamin A and Vitamin K. Vitamins of the B complex may also be lost during processing. All of these should be supplied in appropriate amounts in infant formulas based on soy protein isolates.

Various fats appear to be somewhat less well absorbed from soy-based than from milk-based formulas. Soybean oil or cottonseed oil seem compatible. Alpha galactosides are present in soy formulas and these are indigestible sugars. However, the soy protein isolates contain less of these than the soy flour and they do not pose a problem.

The percentage absorption of minerals from soy-based formulas is less than from milk-based formulas. The presence of phytin in soy products which chelates with minerals is probably one reason for this. The absence of lactose (milk sugar) in such formulas may be another reason. Lactose is known to be effective in improving the absorption of several minerals. However, the actual availability of minerals such as iron can only be properly determined in relation to the processing to which the infant formula is subjected rather than on assumptions on the chelating effect of the phytins in the soy protein isolate. The required mineral and trace element levels can readily be supplied to infant formulas based on soy protein isolate and these requirements appear reasonably well established.

The indications are clear that a well-processed soy protein isolate supplemented with small amounts of L-methionine and fed so as to provide 1.6 g of protein per 100 kcal appears to be nutritionally equivalent in protein quality to cows' milk or human milk fed at the same percentage of calories. To obtain optimum infant feeding results, however, close attention must be paid to the requisite vitamin, mineral, and trace element supplementation and to optimum processing procedures.

In the case of infant allergies to cows' milk, it cannot always be assumed that a soy-based milk will alleviate this problem. Some infants are also allergic to soy protein. Therefore in the U.S. it is not necessary to substitute soy formulas unless an allergy to cows' milk has been established.

CLINICAL FEEDING RESULTS

Despite the shortcomings stated for infant formulas made from soy flour rather than soy protein isolate, clinical feeding studies with normal infants have been recorded that indicate satisfactory weight and length gains comparable to milk-based formulas and satisfactory serum albumin concentrations (4) using soy flour. There was a lower incidence of anal irritation and loose stools with the soy protein isolate formulas, but in other respects, the feeding results were alike.

The price gap, however, between soy flour and isolated soy protein is considerable even after allowing for the increase in protein content when the isolate is produced. At present the price of contained protein from soy flour is $.22/lb vs. $.62/lb from isolate.

This added cost perhaps would not be too significant in a developed country, but in a developing country where income of the lowest income group is small the economic advantage from using soy flour would be significant. It is, of course, true that the soy protein isolate is free of extraneous fiber and indigestible carbohydrate which is helpful with the young infant. However, relatively simple processing of soybeans also can help alleviate this problem.

Conceivably, simple enzymatic treatment of the soy flour dispersion might help to diminish the bulky stools and anal irritation. Recent patents indicate development activities which appear to have this objective in mind. Other formulation approaches also are possible and will be discussed later.

While most infant feeding studies with soy protein isolate show favorable results, some do not. Cherry (5) conducted a careful feeding trial comparing a formula made from isolated soy protein, soy oil, sucrose, and corn syrup solids supplemented with vitamins and minerals with a modified milk formula. In this study the milk formula gave faster growth, especially with the female babies, as measured by weight, length, and head circumference. The same tendency was found with the male babies but not to the same extent as with the girls. It has been indicated that the soy formula in this case may have been deficient in calcium, magnesium, zinc, and possibly methionine. This may explain the disparity in performance between the two formulas. This disparity is in contrast to more recent studies where, for the first time, even malnourished and convalescent infants responded in a satisfactory manner to formulas made with soy protein isolates.

Until recently most infant feeding studies with soy milks were conducted in the U.S. or in Europe with essentially normal infants, although in some cases studies were conducted with small or premature infants. The pioneering studies of Graham (6) in Peru indicated that the far more severe test of effectively feeding malnourished infants could be met with properly formulated soy protein isolate fortified with DL-methionine. The feeding results with his malnourished infants were as satisfactory as those with modified cows' milk control. Graham was careful to point out, however, that in the event a formula was designed in which cows' milk protein and soy protein isolate were compared as the supplement for a cereal or tuber which supplied the main energy source, the milk protein would likely prove to be the superior supplement.

SOY-CEREAL FOOD BLENDS

Up to this point we have considered only infant formulas which were built around soy protein isolate or soy flour and were not blended with cereals as the carbohydrate source. Yet in terms of the needs of the developing world, it is indispensable to consider soy-cereal blends. The U.S. has provided to the developing countries ca. 2.4 billion lb of Corn-Soy-Milk Mix (CSM) and ca. 251 million lb of Wheat-Soy Blend (WSB). It must be realized that CSM and WSB were not intended primarily for early infant feeding but were designed as a valuable dietary supplement for children and adults with some potential as a weaning food.

It is only natural that Agency for International Development and UNICEF should show great interest in the potential of these blends for infant feeding in developing countries. Graham (7) has carried out pioneering infant and child feeding trials on these products and several related modifications. He reported his results to you at this Conference. As a food technologist I have been impressed with the challenge that his new findings present to the food industry. He has found that amino acid composition or protein quality are not the only determinants of nutritional performance for the infant. He emphasized protein digestibility as well as the need for better digestibility and absorption of the non-protein constituents of the diet.

I also would like to emphasize that the physical state of food components can be highly significant in relation to digestion and absorption. Many years ago we were able to show that the digestibility of milk could be improved by homogenization. Instead of forming a relatively compact bolus of milk protein in the early stages of digestion, the homogenization process, which dispersed the cream throughout the milk protein network, resulted in a protein flock which was soft and friable and thus readily amenable to the action of the digestive enzymes. Graham (8) observed with a specially processed sweetened instant corn-soy-milk blend that the special processing of the cornmeal to decrease water holding capacity evidently led to low stool weights and did provide an increase in caloric density. He was able to demonstrate that this formula could provide a major source of protein for normal or convalescent malnourished infants and children.

TECHNOLOGICAL AND MARKETING ASPECTS

It is interesting to note that sterilized soy milk as a beverage has been sold for many years in Singapore, Malaysia, Thailand, Hong Kong, and most likely other Asian countries. It is consumed cold in summer and hot in winter. In Hong Kong, 149 million bottles will be sold this year by the Hong Kong Soya Bean Products Company. In Thailand 33 million bottles will be sold by GreenSpot (Thailand) Ltd. In Singapore and Malaysia, Yeo Hiap Seng Limited probably will market 10 million bottles in 1973. Our information is that persons of all ages consume these products.

These reasonably priced sterilized soy milks are fortified with vitamins and minerals. It would be interesting to determine to what extent they are used in infant feeding and with what results. The processing systems used are fairly sophisticated. The whole beans are soaked, ground and filter pressed, the extract is deodorized and fortified with sugar, flavor, vitamins, and minerals; the blend is homogenized. In the case of the Singapore operation the soy milk is heated to 142 C and held for 4 sec. It is then cooled and filled aseptically into sterilized containers. The useful shelf life of the product is stated to be 8 months.

Recent patent literature and other published literature indicates a growing interest in whey-soy combinations. Some of this interest has been stimulated by a steep rise in the price of non-fat milk solids and by the dwindling supply of this dairy product. Whey has been proposed as at least a partial replacement for the non-fat milk solids in CSM blends. There are nutritional considerations that favor the development of corn-soy-whey blends. The lactose content of sweet dried whey (70%) should be helpful in improving the absorption of minerals and trace elements in infant formulas.

Lactalbumin and lactoglobulin, the primary proteins of whey, have excellent essential amino acid profiles and should have valuable supplementing value even though the protein content of dried whey is only 12%. Whey protein concentrates and isolates are also beginning to move into the marketplace.

The application of fermentation and enzyme technology for improving the digestibility of soy products and soy cereal blends would seem to offer challenging possibilities to food technologists and clinicians who work in the area of infant and weaning foods. Graham's recent feeding trials have confirmed in a quantitative manner that the physical state of the blended components in an infant food has an important relationship to digestion and absorption. There definitely is unfinished challenging business here.

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