SUPPLEMENTATION OF CORN GRUELS WITH WHEY PROTEIN CONCENTRATES FOR PRE-SCHOOL CHILD FEEDING IN GUATEMALA

by

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"...And grinding the yellow and white ears of corn Xmucane made nine drinks and came with food and drink, then created the flesh of man when the creators were making men..."

Popol Vuh, Sacred book of the Mayas

## TABLE OF CONTENTS

## LIST OF TABLES

LIST OF FIGURES

# INTRODUCTION

Corn (or maize) ranks third (after wheat and rice) in the world production of cereals (FAO, 1977). However, corn is a major source (No.2) of vegetable protein in the world. Corn is the basic food for most countries in Latin America, mainly Mexico and Central America, and for some countries in Africa.

Sufficient evidence confirms that maize was used by the primitive inhabitants of Latin America. Corn played an essential role in the culture and religion of the Mayan Indians who prepared several types of foods from this cereal, the "tortilla" being the most important. The Mayas learned by trial, by past experience, or by other means to prepare tortillas using a process of alkaline cooking. The lime treatment process, still used today, results in a product that has more availabe niacin than if it were to be prepared using a simple cooking process with just water. Because the corn is cooked with calcium hydroxide, the tortillas were for the Mayas, and still are for the Latin Americans, a good source of calcium (Behar, 1968).

Data from the Food and Agriculture Organization (FAO, 1962) from 64 countries show that Guatemala is among the countries with highest average consumption of corn (360 g/person/day). This consumption of corn begins at early ages (1-2 years) and increases as age increases (from 64 to 318 g/person/day) (Flores, 1972). Corn consumed as tortillas or gruel plus a small amount of cooked beans constitute the diet of the lower income families in Guatemala (Bressani, 1969). For children between one and two years of age, corn provides 27% of the total protein intake and 33% of the calories of their diets. However, some authors have reported that corn provides up to 76% of the protein intake of preschool children in rural areas (Braham et al., 1969; Bressani, 1969). High frequency of infectious diseases, low birth weight, and other environmental and socio-economic factors, together with low protein concentration and poor protein quality of corn-based diets affect growth and development of Guatemalan children during different stages of the life cycle (Mata et al., 1972).

Extensive research has been done in order to improve the nutritional quality of corn, such as genetic improvement (Bressani and Mertz, 1958; Mertz et al., 1964; Nelson et al., 1965; Mertz, 1968), fortification with synthetic amino acids (Bressani and Scrimshaw, 1958; Bressani et al., 1958, Scrimshaw et al., 1958; Hansen, 1961; Trunswell and Brock, 1961; Bressani et al., 1963; Kies et al., 1965, 1967; Bressani et al., 1972), and supplementation with protein concentrates (Scrimshaw et al., 1957; Bressani and Elias, 1968; Bressani et al., 1972; Viteri et al, 1972). All these alternatives to improve the nutritional quality of corn have their advantages and limitations on a given situation (Altschul, 1972).

The necessity to develop protein-rich food mixtures for use as weanling foods and as supplements to diets poor in quantity and quality of protein, particularly those diets consumed by children, was recognised long ago (Bressani, 1969). As a response to this need, two protein mixtures, CSM (a blend of heat-processed cornmeal, toasted soy flour, and nonfat dry milk used in the U.S Food-for-Peace program; Blended Food Products, Formula No.2) and Incaparina (a mixture of cooked maize supplemented with 0.25% L-lysine HCl and human-grade cottonseed flour, on the Central American market since 1962) have been developed (Bressani, 1975). Recent shortages of nonfat dry milk available to the U.S. Department of Agriculture, together with a two-fold price increase since 1972, have stimulated the search for a substitute to be used in the U.S. Food-for-Peace program (Pallansh, 1974). Recently, numerous studies have shown that whey protein concentrates (WPC's) represent a protein source with considerable potential for blending with cereals to improve their nutritional properties ( Womack and Vaughan, 1972, 1974; Forsum, 1975; Chan et al., 1976; Aguilera and

Kosikowski, 1978; Racotta et al., 1979; Hernandez et al., 1981).

The availability of the raw material to be used in supplementing a given food is an important aspect from the practical and economical points of view (Elias and Bressani, 1972). There is little information about production and utilization of whey in Guatemala. However, data of milk and cheese production in Guatemala give an estimate of 54,000 liters of whey produced daily, which are commonly sold for feed or discharged as waste (Flores, 1983). The objective of this research was to obtain basic data that could be applied to the production of a protein-rich food mixture for Guatemalan pre-school children. The health and nutritional problems of the Central American countries are so serious that every alternative for their solution should be explored (Mata et al., 1972).

The present research, conducted in two parts, explores the supplementation of gruels prepared from lime-treated corn with whey protein concentrates (WPC's). A preliminary study focuses on the development of a standard formula for corn gruels and evaluates sensory parameters of gruels supplemented with WPC's at several levels. The major study evaluates the effects of supplementation with three different WPC's on the organoleptic characteristics, objective measurements, and nutritional value of corn gruels.

# LITERATURE REVIEW

## PROTEIN QUALITY OF CORN

Corn is low in total protein and high in carbohydrates, characteristics that make it, as the other cereals, a good source of energy. Protein content of corn varies, not only among the different varieties, but also depending on environmental factors. Fertilizers and genetic selection can produce varieties with a total protein concentration higher than the normal corn (Bressani, 1972).

The total amount of protein in cereals is low, with rice being the one with the lowest content. Corn contains a slightly lower amount of protein than does wheat. Since the total protein concentration in cereals is low, quality becomes the most important factor, as the nutritive value of proteins in food depends not only on quantity but also on quality. Comparative studies on nutritive value of cereal proteins have shown that protein quality (expressed as protein efficiency ratio obtained in experimental animals) and utilizable protein (the product of the quantity by the quality) are the lowest for corn and sorghum (Bressani, 1972).

The amino acid content of the normal corn protein is more or less constant. Representative values show low concentration of two essential amino acids, lysine and tryptophan, as compared with those values in milk. High values for leucine also are noticeable (Bressani and Mertz, 1958). Among the three protein fractions of corn (prolamins, globulins, and glutelins), zein, a prolamine deficient in lysine and tryptophan, represents 50% of the endosperm (Osborne and Mendel, 1914). Bressani and Mertz (1958)found that as protein concentration increases, content of zein increases and lysine and tryptophan concentration decreases. The variability observed by Bressani and Mertz (1958) suggested a mutation in maize with the desirable chemical and nutritional characteristics. This descovery resulted in a corn with a superior protein value, now known as Opaque II corn.

Data showing the protein quality of several cereals as determined in children using similar nitrogen intakes for various cereals illustrate again that maize protein is one of the lowest in quality, and rice protein is the one of highest quality. This difference is attributed to the essential amino acid profile (Bressani, 1969).

Studies in adults (Trunswell and Brock, 1961, 1962; Kies et al., 1965, 1967) have determined a biological value for corn protein of approximately 46.5% when the level of nitrogen intake is high (more than 7 grams/day) and approximately 57% when the level of nitrogen intake is low (4-5 g/day). Using the average figures of 12 rat studies carried out since 1924, Bressani (1972) calculated a biological value for corn protein of 58% (when there is 9% protein in the diet).

The facts about quality and quantity of corn protein summarized above are of extreme importance in every program that has the objective of improving the nutritional value of maize (Bressani, 1972).

NUTRITIONAL CONSEQUENCES IN LIME TREATMENT OF CORN

In the corn-consuming countries of Latin America corn is processed in different ways for its consumption, the tortilla being the most common in the northern countries and the arepa the most used in the southern countries (FAO, 1954). There is a basic difference in the processing of these two staple foods. In tortilla preparation, whole kernel corn is cooked in alkaline solution; the alkaline cooking process aids in separating the pericarp from the kernel leaving endosperm and germ together. In other parts of Latin America the germ is separated from the endosperm and discharged for the preparation of arepas (Bressani et al., 1958, Bressani and Scrimshaw, 1958). The traditional method for tortilla preparation as described by Bressani et al. (1958) involves the addition of one part of whole corn to two parts of approximately 1% lime solution. The mixture is heated to 80 $^{o}$C for 20 to 45 minutes and then allowed to stand overnight (16 hours). The following day the cooking liquor is decanted, and the corn, now referred to as "Nixtamal", is washed two or three times with water without removing the epicarp or the germ. The nixtamal is then ground to a fine dough called "Masa". About 50 grams of dough are patted flat and cooked on both sides (3 minutes on each side) on a hot clay plate, of which the temperature averages 212 $^{o}$C in the middle and 170 $^{o}$C on the edges (Figure 1).

Cravicto et al. (1945) studied the chemical composition of tortillas made in Mexico. They reported relatively small losses in thiamine, niacin, and riboflavin, and a 40% loss in the carotene content of yellow corn. The phosphorous and iron contents increased 15 and 37% respectively; and because of the treatment with calcium hydroxide solution, the calcium increased 2010%.

Massieu et al. (1949) showed that tortillas were deficient in lysine and tryptophan, and that during preparation, considerable change occurred in the original histidine, threonine, arginine, and tryptophan content of corn.

Figure 1. Method for masa preparation.

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Whole Maize (1 part*)

1% CaOH solution (2 parts*)

Heating 45 min, 80 °C

Allow to stand overnight

Liquor (discharge)

Heated & Soaked corn

Wash with water (three times)

Nixtamal

Washing liquor (discharge)

Grind

MASA

* by weight.

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Ref. Bressani et al., 1958.

Jaffe (1950) described a method used for making arepas in Venezuela and showed large losses of fat, thiamine, riboflavin, and niacin. The Venezuelan method, thus, gives a product nutritionally inferior to that prepared in Mexico and Central America.

Bressani et al. (1958) evaluated the changes in samples of white and yellow corn used by two families in a Guatemalan highland Indian village after tortilla preparation. The researchers found that the combined physical and chemical losses from white corn to masa averaged 60% of the thiamine, 52% of the riboflavin, and 32% of the niacin, as well as 10% of the nitrogen, 44% of the ether-extractable portion, and 46% of the crude fiber. The yellow corn lost 65% of the thiamine, 32% of the riboflavin, 31% of the niacin, and 21% of the carotene originally present, as well as 10% of the nitrogen, 33% of the ether-extractable fraction, and 32% of the crude fiber.

The changes in protein quality from corn to tortilla have been found to be minimal; however, data from studies carried out by Bressani (1972) suggest that tortilla protein is of slightly better quality than corn protein (Table 1). The reasons for this are not quite clear as of yet. However, the author notes that the solubility of tortilla proteins has been found to be different from that of corn proteins, zein being the fraction affected to the largest extent by the process. The solubility in 70% ethanol of this fraction is reduced significantly in the tortilla; this means a reduced physiological availability of zein in the tortilla, allowing a better amino acid balance. However, this improvement in the quality of the protein is not enough to counteract the deficiencies of lysine and tryptophan in the corn protein.

Table 1. Protein quality of maize and tortilla as measured by rat studies

| Material | Weight-gain (g) | PER |
|---|---|---|
| Maize | 26 | 1.13 |
| Tortilla | 32 | 1.21 |

Ref. Bressani, 1972.

## IMPROVEMENT OF CORN PROTEIN QUALITY

The strategy to improve corn protein by means of proportional reduction of zein (a very poor quality protein) was developed by Bressani and Mertz (1958) by selecting varieties from the United States and Guatemala. A solid base for the genetic control of lysine and tryptophan synthesis was established when gene Opaque II was discovered (Mertz et al., 1964). The result was the development of a high-lysine corn variety, possibly at the expense of inhibition of synthesis of zein and increase of proteins of better quality, such as glutenins, albumins, and globulins. The changes in the protein of the endosperm of Opaque II corn resulted in a positively modified amino acid balance. The high nutritional value of Opaque II corn has been demonstrated several times ( Mertz et al.,1964; Mertz et al., 1965; Clark et al., 1967; Gallo et al., 1968; Bressani et al., 1969; Fonseca et al., 1970; Jarquin et al., 1970; Young et al., 1971).

The results of agricultural research indicate that the improved varieties of maize have the potential necessary to fulfill the protein quality requirements. However, the same results also indicate that production, processing, marketing, extension activities, and other considerations associated with the high lysine corn varieties require a considerable amount of time and large investment in terms of money and trained human resources, which most of the developing countries do not have (Lachance, 1972).

Fortification of corn with lysine and tryptophan to improve its protein quality has shown good results under experimental conditions ( Bressani and Scrimshaw, 1958;

Bressani et al., 1958; Hansen, 1961; Trunswell and Brock, 1961; Bressani and Marenco, 1963; Bressani et al., 1963; Kies et al., 1965, 1967a, 1967b; Bressani, 1969; Elias and Bressani, 1972; Viteri et al., 1972; Bressani, 1975). The results of these studies showed the potential of this tec-hnique even though it presented some limitations, particula-rly regarding cost. In 1975, cost was 30 to 40% higher than the price of raw maize, owing mainly to the high price of tryptophan (Bressani, 1975). However, if soybean flour was used as a tryptophan source, the cost would be reduced a great deal (Lachance, 1972). Fortification with amino acids does improve the quality of corn protein but does not im-prove its protein concentration, which is important since corn has a low protein content (Elias and Bressani, 1972).

The qualitative adjustment of the deficient amino acids also can be accomplished by the addition of protein concen-trates containing those amino acids (Bressani and Marenco, 1963). The alternative of improving the nutritional quality of corn by supplementing it with other sources of protein has the advantage of improving protein quality and quantity simultaneously (Elias and Bressani, 1972). The appropriate levels of several supplements necessary to obtain an optimum biological response have been calculated (Elias and Bressa-ni, 1972).

Supplementation of corn has been successfully accomplished by blending heat-processed cornmeal, toasted soy flour, and nonfat dry milk. The resulting blend is the base of CSM (corn-soy-milk) (Blended Food Products, Formula No.2), a high-protein food used in international programs for pre-school children (Senti, 1969).

Another alternative to improve the protein quality of corn is the addition of a protein concentrate in the optimum proportion. Table 2 presents the results of adding soybean flour and lysine to corn (Bressani and Marenco, 1963). Supplementation of masa with soybean flour and lysine gives better results in utilizable protein at lower cost than supplementation of masa with synthetic tryptophan and lysine. Protein-rich food based on cooked maize supplemented with 0.25% L-lysine HCL and human-grade cottonseed flour has been on the Central American market under the name of "Incaparina" since 1962 (Bressani, 1975). Introduction of Incaparina into the diets of populations for which the product was designed is a slow process and depends on a series of socio-economic factors (Elias and Bressani, 1977).

Whey protein concentrates (WPC's) represent a new protein source with considerable potential for blending with cereal proteins to improve their nutritional and functional properties (Morr, 1976).

Table 2. Effect of different supplements on the nutritional value of masa.

| Supplement | Protein | PER | Relative Nutritional Value* | Utilizable Protein (%) |
|---|---|---|---|---|
| Masa alone | 7.9 | 1.26 | 33.7 | 2.66 |
| Masa+0.3% lysine +0.1% Triptophan | 8.0 | 2.78 | 74.5 | 5.96 |
| Masa+soybean flour +0.1% lysine | 9.7 | 2.43 | 65.1 | 6.31 |
| Casein alone | 9.8 | 2.80 | 75.0 | 7.35 |

*, relative to casein
Ref. Bressani and Marenco, 1963.

Racotta et al. (1979) found that a "heat coagulated whey protein" had a beneficial effect in supplementation of tortilla and did not cause any unacceptable flavor change in the products. Hernandez et al (1981) concluded that the addition of dehydrated cheese whey to cereals markedly increased their nutritional value but was most effective when the protein was derived equally from both sources. Studies with young rats showed that dried whey and products made from whey significantly improved the nutritional quality of corn, rice, and wheat as measured by increased weight and protein gains and PER (Womack and Vaughan, 1972, 1974; Forsum, 1975; Chan, et al., 1976). Biological tests performed on both raw and boiled protein mixtures showed WPC to be superior than nonfat dry milk in supplementing maize and rice proteins (Forsum, 1975).

The possibility of improving the nutritional quality of a given food by supplementation with protein concentrates depends on the physico-chemical characteristics of the chosen source of protein (Elias and Bressani, 1972). In the case of milk and other dairy products such as whey, lactose content could be a limiting factor when they are used to supplement cereal products aimed at populations in developing countries (Aguilera and Kosikowski, 1978). Paige et al. (1975) found that 50% of the population of developing countries was lactose intolerant by the age of three years. However, modern technology has made possible the production of WPC's with reduced lactose content (O'Sullivan, 1971). Nevertheless, the majority of the studies of whey supplementation of corn have been carried out with WPC's in which lactose has been partially hydrolized (products with 20-60% lactose) and not with low-lactose WPC's (products with 1-2% lactose).

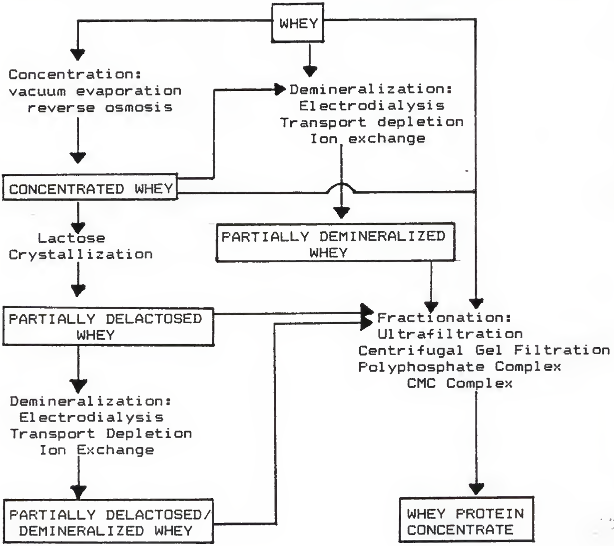
## WHEY PROTEIN CONCENTRATES

Whey, a by-product of cheese manufacture, contains approximately 20% of the protein, 50% of the solids, and all of the lactose of the milk used in cheese processing (Weisberg, 1976; Jelen, 1979). Nine liters of whey are produced for each kilogram of elaborated cheese, but whey is not used in liquid form because of transportation and contamination problems (Holsinger et al., 1974). Cheese processors are adopting modern whey fractionation technology to recover whey proteins and thereby offset the major cost and polution problems of liquid whey disposal (Morr, 1984). The remarkable growth in the number of reports on the utilization of whey and its products indicates that whey processing and utilization is one of the most important areas for research and development in dairying (Mann, 1982).

The various processes for preparing WPC's are outlined in Figure No. 2. Much of the developmental work has been completed for each of these processes and each has been described elsewhere (Hill et al., 1982; Marshall, 1982).

The centrifugal gel filtration process and the ultrafiltration processes are in particular promising for preparing WPC's. This does not imply that one or more of the other processes may not become increasingly important for preparing WPC's to meet special product formulation requirements (Morr, 1976). For example, Thompson and Reiners (1982) have developed a succinylated cheese WPC to be used in coffee whitener and salad dressings. The electrodialysis and transport depletion processes are useful for preparing demineralized WPC. A combination process, which will utilize the advantages of each of these individual processes, is likely to be developed (Morr, 1976).

Figure 2. Process flowchart for preparing WPC's.




Ref. Morr et al., 1973

In a recent review of precipitation and recovery of whey proteins, Hill et al. (1982) concluded that precipitation by heat processing remains the simplest method to recover proteins from sweet and acid wheys. A need to investigate the manufacture and utilization of casein-whey protein co-precipitates and commercial processes for the removal of precipitants, as well as whey processing development using Reverse Osmosis and Ion Exchange processes exists (Hill et al., 1982).

The composition of WPC's is largely a function of the process used to prepare them (Table 3).

**Table 3.** Composition of partially delactosed/demineralized whey protein concentrates.

| Process | Protein | Lactose | Ash | Fat |
|---|---|---|---|---|
| | | | (%) | |
| Ultrafiltration | 50-62 | 15-40 | 0.5-6 | 1.5-15 |
| Centrifugal gel filtration | 50-54 | 25-37 | 11-13 | 0.8-2 |
| Metaphosphate complex | 54-58 | 13 | 10-15 | 3.3-7.3 |
| CMC complex | 50 | 20 | 8 | 1.2 |
| Electrodialysis | 27-37 | 40-60 | 1.4-20 | 2.4-4.3 |

Ref. Morr et al., 1973.

The protein concentration of these WPC's is in the 35% to 60% range. Higher protein concentration by altering the fractionation process to remove more extensively lactose and milk salts is possible.

Whey protein is of an excellent quality, even superior to casein, and can be used to supplement adequately cereals (Womack and Vaughan, 1974; Forsum, 1975; Hernandez et al., 1981). A recent review (Mann, 1982) refers to the utilization of whey proteins in numerous products such as breads, cakes, cheese, beverages, dairy products, confections and desserts, dietary products, meats, etc. Womack and Vaughan (1974) point out that the use of WPC as alternate to non-fat dried milk in many food mixtures might be a more practical contribution to the solution of world protein deficits than attempts to isolate whey constituents for specialized markets.

For most food applications, WPC should be prepared with the proteins in a soluble and functional state. Care is required at all processing steps that involve heating, agitation, and pH adjustment to avoid protein denaturation and concomitant loss of solubility (Morr, 1976). After unfolding, denatured whey protein molecules undergo extensive protein-protein interaction which is a function of temperature, pH, and calcium content. These interactions result in large molecular weight aggregates which impart excessive turbidity, and are, therefore, unsuitable for certain food and beverage applications (Morr et al., 1973; Holsinger et al., 1973). Significant differences have been observed for relative susceptibility to denaturation by each of the major whey protein components at various processing stages. For example, the proteose-peptones are especially resistant and lactalbumin is most susceptible to heat denaturation (Morr et al., 1973).

Whey protein concentrates prepared by mild processing conditions are essentially free of off-flavors and odors. However, if care is not taken to minimize heat treatments, undesirable brown pigments and associated off-flavors are produced during WPC processing and storage by Maillard interaction of proteins with lactose, especially in the the alkaline pH range. This Maillard browning reaction also reduces the nutritional value of whey protein concentrates through a reduction of available lysine (Holsinger et al., 1973).

The functional properties of WPC listed by protein suppliers are extensive. However, the most common functional properties ascribed to WPC are, according to Morr (1976):

Dispersability/Solubility
Viscosity/Stabilization
Elasticity/Cohesion/Adhesion
Dough properties
Emulsification
Foam expansion and stability
Water sorption
Gelation/Fiber formation

There is considerable variation in the functional properties of WPC prepared by each of the major processes (Morr et al., 1973). This is probably due to differences in the extent of removal of lactose, salts, and other non-protein components, protein denaturation, or the presence of residual protein precipitants. Other factors such as type, source, composition and treatment also may alter the functional properties of the WPC (Morr, 1976).

Solubility is an important functional property of whey protein concentrates. Complete solubility of the proteins is a requisite for optimum functionality in foams, emulsions, beverages, and similar applications. In some cases whey proteins may be soluble and in a non-aggregated state so that they can thoroughly mix with the other ingredients of the formulation (Holsinger et al., 1973). In order to accomplish this in food systems throughout the pH range of 3 to 8 and in the presence of calcium ions, the proteins must be in an undenatured state. Otherwise, they will aggregate and precipitate when incorporated into such food systems and fail to provide adequate functionality (Morr, 1976). Dispersability and solubility properties of whey protein have made possible the use of WPC's in various products, like corn-soy-whey mixtures processed either by roll-cooking or extrusion. (Aguilera and Kosikowski, 1978).

Although the technologies for WPC processing have been fairly developed, they have not been as universally adopted by the industry as had been projected. However, prospects still appear bright for this development. Approximately 1,338 million lb of whey proteins are contained in about 187.4 billion lb of cheese whey produced in the world (Zall, 1983). An additional 99-110 million lb of whey proteins could potentially be manufactured from the whey that results from casein manufacture (Morr, 1984). U.S. production of WPC is estimated at about 15.4 million lb (WPI, 1983). The present capacity to produce WPC exceeds the demand for the product by a factor of about 2-3 (Morr, 1984). The trend toward greater production of whey protein concentrates is likely to continue, perhaps at an accelerating rate.

# PRELIMINARY STUDY

## DEVELOPMENT OF STANDARD FORMULA AND SELECTION OF LEVEL OF WPC SUPPLEMENTATION

## MATERIALS AND METHODS

### Ingredients

Yellow corn was obtained from the Kansas State University Department of Agronomy and was a blend of the following commercial hybrids adapted to Kansas: Dekalb XL22, O's Gold 5291, Pioneer 3183, and Northrop PX95.

The following Whey Protein Concentrates (WPC's) were obtained directly from their manufacturers:

1. Regular (REG) WPC- Extra Grade Non-hygroscopic whey (Mid America Dairyman, Springfield, MO.), containing 12% protein and approximately 76% lactose.
2. Partially Delactosed (PD) WPC- Daritek (Foremost-McKesson Foods Group, San Francisco, CA.), spray-dried, processed by ultrafiltration, containing 35.7% protein and 53.0% lactose.
3. Delactosed (DELAC) WPC- Alacen 866 (New Zealand Milk Products Inc., Petaluma, CA.), spray-dried, low lactose WPC, containing 79.9% protein and 1.2% lactose.

Granulated cane sugar was selected because of its similarity to Guatemalan sugar. Iodized salt was used for seasoning. Distilled deionized water was used because it is odorless and virtually tasteless.

## Methods

### 1. Development of standard formula.

Corn was prepared according to a traditional method for masa preparation (Bressani et al., 1958). The grinding of the masa was performed in a 6-inch diameter, 1-HP stone grinder (Curry Company, San Antonio, TX)(Figure 3) at Kansas State University Department of Grain Science and Industry, using 0.06 inch of separation between the stones. The masa was stored in individual packages of 2000 grams each at freezing temperatures (-4 $^{o}$C) until used.

Different amounts of distilled deionized water, salt, and sucrose were tested to establish a standard formula for corn gruels. Mixing methods, cooking times and temperature also were tested. The criteria for the selection of standard formula was based on previous experience of corn gruels prepared commonly in Guatemala. The procedure for preparation of gruel is found in Appendix A.

Figure 3. Stone grinder

2. Sensory evaluation for determination of WPC level of supplementation.

To select the level of WPC supplementation the following combinations of Masa:WPC (by weight) were tested:

100:0 (Reference sample)

90:10

85:15

80:20

75:25

A sensory panel consisting of 6 trained judges, menbers of The Sensory Center of Kansas State University Departnent of Foods and Nutrition, evaluated the different combinations of Masa:WPC. During preliminary sessions the judges expressed difficulty in identifying whey flavor and aroma, attributed to the heterogeneity of these organoleptic characteristics of WPC's and to the interference of the strong predominant lime-treated corn flavor and aroma. For this reason, the intensities of masa aroma and masa flavor were chosen to be evaluated. The judges were trained during two preliminary sessions. The panelists also were trained to use score cards (Appendix B). A reference sample was prepared using the standard formula and was served together with each of the samples for comparison in evaluating the following factors:

<u>Masa aroma.</u> The smell of lime-treated corn as perceived through the nose as more than, less than, or equal to the reference sample.

<u>Masa flavor.</u> The taste of lime-treated corn when the gruels were eaten as more than, less than, or equal to the reference sample.

<u>Consistency.</u> The degree of thickness of the gruels as perceived visually when stirred and as perceived in the mouth as thinner than, thicker than, or equal to the reference sample.

<u>Texture.</u> The sensation of gruels in the mouth in terms of smoother than, less smooth than, or equal to the reference sample. The term "less smooth" included grittiness, lumpiness, nuttiness, and graininess.

<u>Color.</u> The appearance of the gruels to the eye as darker than, lighter than, or equal to the reference sample.

The judges were asked to evaluate the aroma first, then consistency, flavor, and texture. Afterwards, color of the gruels placed on a white plate was evaluated under a constant north light source (MacBeth Skylight, model No. BX848A, MacBeth Daylighting Corp., Newburg, NY). Freshly prepared gruel samples were placed in 100-ml Pyrex custard cups pre-heated in an electric oven ( Frigidaire, model RCD-71-59, General Motors Co., Dayton, OH.) at 76 $^{o}$C and covered by watch glasses. Plastic spoons were used by judges to evaluate the gruels. Distilled deionized water was provided to rinse the mouth between samples. The amount of gruel to be ingested was not restricted. During each session six sets of two samples together with a reference sample were presented to the panelists. The judges were asked to evaluate the indicated parameters comparing each of the two samples, marked with random codes, to the reference sample, marked "R". A three-to-five-minute break was allowed between each set of samples. Each session lasted approximately one hour 30 minutes. A total of three sessions were conducted.

Experimental design and analyses of data.

The experiment was conducted as a Balanced Incomplete Block Design (Snedecor and Cochran, 1967) (Table 4). The model assured that every combination of Masa:WPC was evaluated once with each of the others. The presentation of samples to the judges was randomized; however, each judge received identical samples at a time because of practical reasons for the preparation of the samples. The type of WPC evaluated during each session was assigned randomly.

Table 4. Balanced Incomplete Block Design for sensory evaluation of different combinations of Masa:WPC (by weight).

| Session No. | Type of WPC | Order of preparation and presentation I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|---|
| 1 | REG | 90:10 | 90:10 | 85:15 | 90:10 | 80:20 | 85:15 |
| | | 80:20 | 85:15 | 75:25 | 75:25 | 75:25 | 80:20 |
| 2 | PD | 90:10 | 90:10 | 85:15 | 85:15 | 80:20 | 90:10 |
| | | 75:25 | 85:15 | 75:25 | 80:20 | 75:25 | 80:20 |
| 3 | DELAC | 85:15 | 80:20 | 90:10 | 90:10 | 85:15 | 90:10 |
| | | 75:25 | 75:25 | 80:20 | 75:25 | 80:20 | 85:15 |

An 11-point scale was assigned to each of the parameters evaluated (Appendix C). The judges were not aware of these scores in order to avoid ranking of the samples. The positive and negative signs were assigned arbitrarily for the purpose of determining the direction of the difference between samples and reference sample and, thus, do not indicate desirability of any particular characteristic. An overall score was furnished by adding the absolute values of the scores corresponding to each paramenter. Scores for masa aroma, masa flavor, consistency, texture, and color, along with overall scores were subjected to Analyses of Variance (Snedecor and Cochran, 1967). The F-test was used to test the hypothesis that the mean scores of all treatments for a given combination of Masa:WPC were the same. Least Significant Differences procedure was used to separate the means when the F-test rejected such hypotheses.

The Analysis of Variance (AOV) for sensory evaluation data was:

| Source of Variation | Degrees of Freedom |
|---|---|
| Treatments | 3 |
| Order of presentation | 5 |
| Error | 3 |
| Total | 11 |

## RESULTS AND DISCUSSION

1. Development of standard formula.

The selected standard formula utilized in the study is shown in Table 5.

2. Sensory evaluation for determination of WPC level of supplementation.

Color. No significant difference in color was found among all combinations when REG WPC was used (Table 6).

Table 5. Standard formula for corn gruels

| Ingredients | Amount |
|---|---|
| Masa | 100 g. |
| Sucrose | 12 g. |
| Salt | 1 g. |
| Distilled water | 300 ml. |

A difference ($p<0.01$) in color was found among gruels prepared with FD WPC. The combination 90:10 was lighter ($p<0.05$) than the other combinations of masa:FD WPC (Table 7). No significant difference was found between gruels prepared with 25 and 20 grams of FD WPC; however, gruels supplemented with 20 grams of FD WPC were darker ($p<0.05$) than gruels supplemented with 15 grams of the same type of WPC. When DELAC WPC was used to supplement the gruels, a difference ($p<0.05$) in color was found (Table 6). Gruels prepared with 10 grams of DELAC WPC were lighter ($p<0.05$) than gruels prepared with 15, 20, or 25 grams of the same type of WPC (Table 7). The combination 85:15 was lighter ($p<0.05$) than the combination 75:25, but no diference was found between combinations 80:20 and 85:15 and combinations 75:25 and 80:20.

Table 6. Mean squares and F-values from AOV for sensory evaluation of different combinations of masa:WPC.

| Sensory parameter | REG WPC | | PD WPC | | DELAC WPC | |
|---|---|---|---|---|---|---|
| | Mean square | F value | Mean square | F value | Mean square | F value |
| Color | 0.458 | 5.21 | 0.951 | 37.36** | 1.727 | 14.92* |
| Texture | 1.065 | 1.58 | 1.243 | 35.80** | 0.620 | 1.22 |
| Consistency | 1.458 | 7.87 | 1.674 | 80.33** | 0.465 | 0.52 |
| Masa flavor | 1.523 | 9.97* | 1.523 | 9.97* | 0.553 | 26.56* |
| Masa aroma | 1.000 | 6.00 | 1.044 | 2.02 | 0.086 | 5.29 |
| Overall score | 22.671 | 22.06* | 26.349 | 47.23* | 2.419 | 1.02 |

*, p<0.05; **, p<0.01

Texture. No significant differences in texture were found among all levels of supplementation when REG WPC or DELAC WPC was used (Table 6). When PD WPC was used, a difference (p<0.01) in texture was found. Gruels prepared with 20 or 25 grams of PD WPC were smoother (p<0.05) than gruels prepared with 10 or 15 grams of the same WPC; however, no significant differences in texture score were found between combinations 90:10 and 85:15 (Table 7).

Table 7. Least square means* of sensory evaluation of different combinations of masa:WPC.

| Combinations | Color | Texture | Consistency | Masa flavor | Masa aroma | Overall score |
|---|---|---|---|---|---|---|
| Masa:REG WPC | | | | | | |
| 90:10 | $0.555^{a}$ | $1.222^{a}$ | $-1.278^{a}$ | $-0.778^{a}$ | $-1.667^{a}$ | $6.833^{a}$ |
| 85:15 | $1.111^{a}$ | $2.056^{a}$ | $-2.722^{a}$ | $-1.333^{ab}$ | $-1.778^{a}$ | $9.889^{b}$ |
| 80:20 | $1.722^{a}$ | $3.056^{a}$ | $-2.944^{a}$ | $-2.333^{bc}$ | $-2.667^{a}$ | $13.389^{c}$ |
| 75:25 | $1.833^{a}$ | $3.556^{a}$ | $-3.889^{a}$ | $-2.778^{c}$ | $-3.111^{a}$ | $15.167^{c}$ |
| Masa:FD WPC | | | | | | |
| 90:10 | $0.611^{a}$ | $1.444^{a}$ | $-1.333^{a}$ | $-0.778^{a}$ | $-1.667^{a}$ | $7.000^{a}$ |
| 85:15 | $1.167^{b}$ | $1.611^{a}$ | $-2.661^{b}$ | $-1.333^{ab}$ | $-2.444^{a}$ | $9.889^{b}$ |
| 80:20 | $2.278^{c}$ | $2.944^{b}$ | $-3.056^{c}$ | $-2.333^{bc}$ | $-3.000^{a}$ | $14.167^{c}$ |
| 75:25 | $2.444^{c}$ | $3.222^{b}$ | $-3.333^{c}$ | $-2.778^{c}$ | $-3.389^{a}$ | $15.167^{c}$ |
| Masa:DELAC | | | | | | |
| 90:10 | $1.389^{a}$ | $2.611^{a}$ | $-2.722^{a}$ | $-3.167^{a}$ | $-3.778^{a}$ | $14.556^{a}$ |
| 85:15 | $2.556^{b}$ | $1.889^{a}$ | $-2.778^{a}$ | $-3.556^{b}$ | $-3.944^{a}$ | $15.044^{a}$ |
| 80:20 | $3.389^{bc}$ | $2.222^{a}$ | $-2.722^{a}$ | $-4.000^{c}$ | $-4.056^{a}$ | $16.056^{a}$ |
| 75:25 | $3.778^{c}$ | $3.005^{a}$ | $-3.167^{a}$ | $-4.056^{c}$ | $-3.889^{a}$ | $17.278^{a}$ |

*, Means of scores from 6 judges.
abc, Means followed by the same letter within a column are not significantly different ($p<0.05$).

Consistency. No significant differences in consistency were found among all combinations of masa:REG WPC or masa:DELAC WPC; however, gruels supplemented with PD WPC showed a difference ($p<0.01$) (Table 6). Gruels prepared with 10 grams of PD WPC were thicker ($p<0.05$) than gruels prepared with 15, 20 or 25 grams of the same type of WPC (Table 7). No significant difference in consistency was found between combinations 75:25 and 80:20, but both were thinner ($p<0.05$) than the combination of 85 grams of masa and 15 grams of PD WPC.

Masa flavor. The results of masa flavor evaluation showed differences ($p<0.05$) among the levels of supplementation with all types of WPC (Table 6). When DELAC WPC was used to supplement the gruels, a decrease ($p<0.05$) in masa flavor as the level of supplementation went from 10 to 15 and from 15 to 20 grams was found, but no significant difference was found when the level of supplementation went from 20 to 25 grams (Table 7). Partially delactosed WPC and REG WPC showed identical results for masa flavor. No significant differences in masa flavor were found between subsequent levels of supplementation when REG WPC or PD WPC was used; however, the gruels had less ($p<0.05$) masa flavor as the level of supplementation went from 10 to 20, and from 15 to 25 grams of either REG WPC or PD WPC. Racotta and co-workers (1979) found no significant differences between flavor scores of tortillas supplemented with 35 and 25% heat coagulated WPC.

Masa aroma. Masa aroma of corn gruels supplemented with REG or PD WPC had the tendency to diminish as the amount of supplement increased (Table 7); however, no significant differences in scores for masa aroma were found among all levels of supplementation when either REG WPC, PD WPC, or DELAC WPC was used (Table 6).

Overall score. Overall differences among combinations were found when gruels were supplemented with PD WPC ($p<0.05$) or with REG WPC ($p<0.05$), but not with DELAC WPC (Table 6). Gruels supplemented with REG WPC and PD WPC showed similar results (Table 7). No significant differences in overall score were found between the combinations 75:25 and 80:20 when either REG WPC or PD WPC was used. The combination 85:15 received a lower ($p<0.05$) overall score than did the two combinations mentioned above, and the combination of 10 grams of WPC and 90 grams of masa presented the lowest ($p<0.05$) overall scores among all the combinations using REG WPC or PD WPC.

In general, the results of the sensory evaluation of the different combinations of Masa:WPC indicated that, for REG WPC and PD WPC, the combination 90:10 was the combination that differed the least from the reference sample;

therefore, it was selected as the level of supplementation to be used in the second stage of this study. The combination 90:10 was not significantly different from the others when DELAC WPC was used; however, in order to achieve uniformity when comparing the three WPC's, it also was selected as the level of DELAC WPC supplementation to be used in the major study.

# MAJOR STUDY

## SENSORY EVALUATION, OBJECTIVE MEASUREMENTS AND NUTRITIONAL QUALITY OF CORN GRUELS SUPPLEMENTED WITH DIFFERENT WPC's.

## MATERIALS AND METHODS

### Ingredients

The specifications for the ingredients used in the major study and for the ingredients used in the preliminary study are the same (pp. 25-26).

### Methods

1. Sensory Evaluation of corn gruels supplemented with different types of WPC.

After the WPC supplementation level was selected, corn gruels prepared with REG, PD, and DELAC WPC's were compared. A sensory panel consisting of the same trained judges and following the same procedure outlined in the Preliminary Study was conducted (pp. 27-29).

### Experimental design and analyses of sensory data.

The sensory evaluation of gruels supplemented with different WPC's was conducted in one session as a Balanced Incomplete Block Design (Snedecor and Cochran, 1967) (Table 8). The model assured that each type of WPC was evaluated twice with each of the others. Scores for color, texture, consistency, masa aroma, and masa flavor were furnished using an 11-point scale (Appendix D). Overall scores were calculated as indicated in the Preliminary Study (p. 30).

Table 8. Balanced Incomplete Block Design for sensory evaluation of corn gruels supplemented with different types of WPC.

| Order of preparation and presentation of samples | | | | | |
|---|---|---|---|---|---|
| I | II | III | IV | V | VI |
| DELAC | REG | REG | PD | DELAC | PD |
| REG | PD | DELAC | REG | PD | DELAC |

Analysis of Variance (AOV) was used to study the treatment effects of types of WPC at a given level of supplementation (90:10, masa:WPC by weight) on selected sensory parameters. Least Square Means were compared to determine treatment effects. When F-values were significant, Least Significant Differences were calculated at 5% level to determine significance of differences between means (Snedecor and Cochran, 1967). The Analysis of Variance for the data was:

| Source of variation | degrees of freedom |
|---|---|
| Treatments | 2 |
| Order of presentation | 5 |
| Error | 4 |
| Total | 11 |

2. Objective Measurements of corn gruels supplemented with different types of WPC.

Spectrophotometric measurements. One tablespoonful of each gruel was cooled to room temperature (23 $^{o}$C) and placed in an optically clear cup (6 cm in diameter) for measurement in a HunterLab Spectrophotometer (model D54P-5, Hunter Associates Laboratory, Reston, VA.). In preliminary laboratory work, spectrophotometric values and wavelength that best described the color of corn gruels were determined (Appendix D). Those were L- value, a-value, b- value, and Percentage Reflectance at 520 nanometers (nm). L-values are used to determine the lightness (or brightness) of a given color. The redness, greeness, yellowness, and blueness are measured by +a, -a, +b, and -b values, respectively. Percentage reflectance measures the amount of light that is reflected from a food when hit by a source of light (Hunter, 1975). The incident light in the instrument was illuminant C, as it emits the most uniform radiant energy. The instrument was standardized using a white ceramic plate with an L-value of 100. Six replicate samples were used for spectrophotometric measurements. Four readings, rotating the cup 90° each time, were taken and the means of four readings were recorded.

pH measurements. One hundred gram samples were placed in 100-ml beakers and cooled to room temperature (23°C). pH measurements were taken in a Horizontal Ecology (model 5998-10) pH meter using AOAC procedures (AOAC, 1980). Duplicate pH readings of six replicate samples were taken and the means of two readings were recorded.

Experimental Design and Analysis of data on objective measurements.

Preparation of corn gruels and colection of objective measurements were ramdomized completly. pH and spectrophotometric data were subjected to Analysis of Variance (AOV) and Least Significant Differences procedure (Snedecor and Cochran, 1967). The AOV for spectrophotometric and pH measurements was:

| Source of variation | Degrees of freedom |
|---|---|
| Treatments | 3 |
| Error | 20 |
| Total | 23 |

3. Nutritional Quality of corn gruels supplemented with different types of WPC.

Proximate Analyses. Proximate analyses were performed on six replicate samples of corn gruels in order to have a description of the basic composition of the products. Moisture, fat, fiber, and ash were analyzed according to AOAC procedures (AOAC, 1980). Carbohydrate content was obtained by difference. Nitrogen content was determined by the Kjeldahl method, and the factor 6.25 was used to obtain the crude protein content (AOAC, 1980). Two replicate samples of raw corn and six replicate samples of masa were also subjected to proximate analyses following the same procedures as above.

Amino acid composition. One hundred grams of freshly prepared samples were freeze-dried in individual plastic trays for 24 hrs. in a Virtis freeze-drier (Model 10-MR-TR, The Virtis Company, Gardiner, N.Y.). Amino acid composition of the products was determined after protein hydrolysis with p-toluenesulfonic acid (Liu and Chang, 1971), using a DIONEX (D300 Kit) Single-column Accelerated Amino Acid Analysis System (DIONEX Chemical Corporation, Sunnyvale, CA) (Benson, 1972). Corn, masa, and WPC's also were analyzed for amino acid composition using the same procedure. Tryptophan was not determined because of its destruction during the acid hydrolysis. Amino acid composition analyses were run in only one sample of each treatment.

Chemical score. The Chemical scores were determined using the 1973 FAO/WHO provisional amino acid scoring pattern (FAO/WHO, 1973) and by applying the following formula (Mitchell and Block, 1946):

$$\text{Chemical score} = \frac{\text{mg amino acid/g test prot.}}{\text{mg amino acid/g reference prot.}} \times 100$$

Energy values. The caloric content of the gruels was estimated from the proximate analyses of the products in order to compare it with the FAO caloric allowance for pre-school children (FAO/WHO, 1973). The factors used for calculating the energy values of the products were 4 Kcal/gram of carbohydrate, 4 Kcal/gram of protein, and 9 Kcal/gram of fat.

Lactose content. Lactose content of gruels was calculated from amounts of WPC added and lactose content of the WPC's reported by their manufacturers.

Experimental design and analysis of data on nutritional quality.

Preparation of treatments and collection of data on proximate analyses were ramdomized completely. These data were analyzed by Analysis of Variance (AOV) and Least Significant Differences procedure (Snedecor and Cochran, 1967). The AOV for proximate analysis data was:

| Source of variation | Degrees of Freedom |
|---|---|
| Treatments | 3 |
| Error | 20 |
| Total | 23 |

## RESULTS AND DISCUSSION

### 1. Sensory evaluation of corn gruels supplemented with different types of WPC.

Color A difference ($p<0.05$) in color was found among gruels supplemented with different WPC's (Table 9). Gruels prepared with DELAC WPC were lighter ($p<0.05$) than gruels prepared with REG WPC or with PD WPC; however, no significant difference in color was found between gruels supplemented with REG WPC and gruels supplemented with PD WPC (Table 10).

Texture No significant differences among texture scores of gruels supplemented with different types of WPC were found (Table 9).

Table 9. Mean squares and F-values from AOV of sensory evaluation of corn gruels supplemented with different types of WPC[a].

| Sensory parameter | Mean square | F-value |
|---|---|---|
| Color | 1.231 | 17.16* |
| Texture | 0.676 | 0.91 |
| Consistency | 0.259 | 1.06 |
| Masa flavor | 0.472 | 4.81 |
| Masa aroma | 1.974 | 9.53* |
| Overall score | 21.419 | 5.69 |

a, Supplementation level, 90:10 masa:WPC (by weight).
*, Significant difference ($p<0.05$)

Table 10. Least square means of sensory evaluation scores for corn gruels supplemented with different types of WPC*.

| Treatment | Color | Texture | Consistency | Masa flavor | Masa aroma | Overall score |
|---|---|---|---|---|---|---|
| Masa:REG | $0.917^{a}$ | $1.125^{a}$ | $-2.375^{a}$ | $-1.125^{a}$ | $-1.750^{a}$ | $9.000^{a}$ |
| Masa:PD | $0.792^{a}$ | $2.000^{a}$ | $-2.000^{a}$ | $-1.542^{a}$ | $-2.333^{a}$ | $8.125^{a}$ |
| Masa:DELAC | $2.125^{b}$ | $2.500^{a}$ | $-3.042^{a}$ | $-3.375^{a}$ | $-3.500^{b}$ | $14.708^{a}$ |

*, Supplementation level, 90:10 masa:WPC (by weight).
ab, Means followed by the same letter within the same column are not significantly different.

Consistency No significant Difference in consistency among all the treatments was found (Table 9).

Masa flavor No significant difference for masa flavor scores was found among gruels supplemented with REG, PD and DELAC WPC's (Table 9).

Masa aroma The aroma scores showed a difference ($p<0.05$) among gruels supplemented with different types of WPC (Table 9). Gruels supplemented with DELAC WPC had less ($p<0.05$) masa aroma than gruels supplemented with REG WPC or PD WPC (Table 10). No significant difference in masa aroma was found between gruels supplemented with REG WPC and gruels supplemented with PD WPC.

Overall score The overall scores were calculated by adding the absolute values of the five sensory scores as an indicator of the overall differences among the treatments and with respect to the reference sample. No significant difference in overall score (Table 9) found among treatments indicates, in general terms, that the three WPC's utilized in this study do not differ in their overall effect on the sensory characteristics of corn gruels when added in a proportion of 90:10 (masa:WPC) by weight. However, considering the sensory parameters individually, the score that contributed to a greater extent to furnish the overall score and, therefore, the parameter that was most affected by the addition of WPC, was masa aroma for both DELAC WPC and PD WPC, and consistency for REG WPC. Masa flavor and consistency also were affected considerably by the addition of DELAC WPC.

DELAC WPC lightens the color and reduces the masa aroma more than do the other two WPC's, which suggests that REG WPC or PD WPC would be more suitable for supplementation of corn gruels if a minimum change in the eating habits of the target population is pursued. But the present evaluation is not measuring acceptability or preference, and no evidence found indicates that gruels with lighter color or with less masa aroma will not be accepted well by the target population.

2. Objective measurements of corn gruels supplemented with different types of WPC.

Spectrophotometric measurements.

Differences ($p<0.001$) in L-, a-, and b-values, as well as in percentage reflectance were found among all the treatments (Table 11). Gruels supplemented with REG WPC or PD WPC were lighter ($p<0.05$) than non-supplemented gruels, but no significant difference in L-values was found among gruels prepared with these two WPC's (Table 12). The supplementaton of corn gruels with DELAC WPC resulted in products with the highest ($p<0.05$) L-values, which indicates that this WPC lightens the corn gruels to a greater extent than do the other two WPC's. These results agree with color scores obtained by sensory evaluation (Table 10).

No significant difference in a-values was found among non-supplemented gruels, gruels supplemented with REG WPC, and gruels supplemented with DELAC WPC (Table 12). Small positive a-values indicate the presence of a weak red component in the color of these gruels. However, gruels supplemented with PD WPC showed lower ($p<0.05$) a-values

Table 11. Mean squares and F-values from AOV of spectrophotometric and pH measurements of corn gruels supplemented with WPC's[a].

| Measurement | Mean square | F-value |
|---|---|---|
| L-value | 8.475 | 133.19*** |
| a-value | 0.109 | 10.46*** |
| b-value | 0.469 | 9.13*** |
| % Reflectance | 15.664 | 194.14*** |
| pH | 0.459 | 62.88*** |

a, Supplementation level, 90:10 masa:WPC (by weight).
***, ($p<0.001$).

Table 12. Least square means* of spectrophotometric and pH measurements of corn gruels supplemented with WPC's.

| Treatment | L-value | a-value | b-value | % Reflectance | pH |
|---|---|---|---|---|---|
| Control | 63.085$^{c}$ | 0.222$^{a}$ | 23.965$^{b}$ | 32.165$^{c}$ | 7.055$^{a}$ |
| Masa:REG | 63.667$^{b}$ | 0.223$^{a}$ | 24.263$^{a}$ | 32.628$^{b}$ | 6.557$^{b}$ |
| Masa:PD | 63.512$^{b}$ | -0.063$^{b}$ | 23.823$^{bc}$ | 32.833$^{b}$ | 7.065$^{a}$ |
| Masa:DELAC | 63.747$^{a}$ | 0.122$^{a}$ | 23.595$^{c}$ | 35.725$^{a}$ | 6.608$^{b}$ |

*, Means of 6 replications

**, Supplementation level, 90:10 masa:WPC (by weight).

abc, Means followed by the same letter within the same column are not significantly different.

than did the other treatments. Small negative a-values of gruels supplemented with PD WPC indicate the presence of a weak green component in the color of these gruels.

The b-values are relatively high since they describe the predominat yellow component of the gruels color. Gruels supplemented with REG WPC were yellower ($p<0.05$) than the other gruels (Table 12). Gruels supplemented with DELAC WPC were less ($p<0.05$) yellow than non-supplemented gruels. When gruels were supplemented with with PD WPC, no significant difference in b-values were found as compared with the control or as compared with gruels supplemented with DELAC WPC.

Percentage reflectance was lower ($p<0.05$) for non-supplemented gruels (Table 12). For supplemented gruels no significant difference was found among the amount of light reflected by either gruels containing REG WPC or gruels containing PD WPC. However, gruels supplemented with DELAC WPC reflected more ($P<0.05$) light, and, therefore, were lighter than the other gruels. Results of percentage reflectance agree with the results for L-values, since the lighter the object is, the more light it will reflect, and vice versa.

In general, the results of spectrophotometric measurements indicate that the use of WPC's to supplement corn gruels gives lighter products. When REG WPC is used, the products are yellower; when DELAC WPC is used, the products are creamier, and when PD WPC is used, no significant difference in yellowness is measured.

<u>pH measurements.</u>

A difference ($p<0.05$) in pH among the treatments was found (Table 11). The supplementation of corn gruels with either REG WPC or DELAC WPC resulted in a product with lower ($p<0.05$) pH, while the addition of PD WPC did not alter the pH of corn gruels (Table 12). pH measurements of WPC's (Appendix E) showed that a 10% solution of PD WPC had a pH of 7.18, while 10% solutions of REG and DELAC WPC had pH's of 6.00 and 6.18, respectively.

3. <u>Nutritional quality of corn gruel supplemented with different types of WPC.</u>

<u>Proximate analysis.</u>

No significant differences in moisture, fat (ether extract), and crude fiber contents were found among all treatments (Table 13). Differences in ash ($p<0.05$), nitrogen ($p<0.001$), protein ($p<0.001$), and carbohydrates (nitrogen free extract) ($p<0.001$) contents were found among all gruels.

Table 13. Mean squares and F-values from AOV of proximate analysis of corn gruels supplemented with WPC's.[a]

| Variable | Mean square | F-value |
|---|---|---|
| Moisture | 2.852 | 0.44 |
| Ash | 0.446 | 4.49* |
| Nitrogen | 293.108 | 130.90*** |
| Crude protein | 115.200 | 130.76*** |
| Ether extract | 0.196 | 2.93 |
| Crude fiber | 0.130 | 1.74 |
| Nitrogen free extract | 105.258 | 182.88*** |

a, Supplementation level, 90:10 masa:WPC (by weight).
*, $p<0.05$; ***, $p<0.001$.

Supplementation of corn gruels with REG WPC resulted in products with higher ($p<0.05$) ash content, while the addition of DELAC or PD WPC's did not affect the ash content of corn gruels (Table 14). The process of making REG WPC does not remove as much minerals as does the processing of PD WPC and DELAC WPC (McDonough et al., 1974).

Table 14. Least squares means for proximate analysis of corn gruels supplemented with WPC's*.

| Variable | Treatments | | | |
|---|---|---|---|---|
| | Control | REG | PD | DELAC |
| Moisture (%) | 82.20 a | 81.27 a | 81.53 a | 80.53 a |
| Ash (%) | 2.88 a | 3.49 b | 2.96 a | 3.09 a |
| Nitrogen (mg/g) | 14.15 a | 16.16 b | 19.34 c | 29.86 d |
| Crude protein (%) | 8.84 a | 10.10 b | 12.09 c | 18.69 d |
| Ether extract (%) | 2.52 a | 2.39 a | 2.10 a | 2.24 a |
| Crude fiber (%) | 1.17 a | 1.08 a | 0.83 a | 0.97 a |
| Nitrogen free extract (%) | 84.71 a | 82.94 b | 82.15 b | 75.17 c |

*, Supplementation level, 90:10 masa:WPC (by weight).
abcd, Means followed by the same letter within the same row are not significantly different.

The results of nitrogen and crude protein contents reflects the three levels of protein content of the WPC's utilized in this study. Supplementation of corn gruels with WPC's resulted in products with higher($p<0.05$) protein content. As expected, the gruels supplemented with DELAC WPC showed the highest protein content, followed by gruels supplemented with PD WPC, and finally by gruels supplemented with REG WPC (Table 14).

Corn gruels supplemented with DELAC WPC had lower ($p<0.05$) carbohydrate content (expressed as nitrogen free extract) than non-supplemented gruels and gruels supplemented with the other two WPC's (Table 14). This is a result of the low lactose concentration (1.2%) and low content of other carbohydrates (9.8%) found in DELAC WPC utilized in this study. No significant difference was found between the nitrogen free extract of gruels supplemented with REG WPC and gruels supplemented with PD WPC; however, they both showed lower ($p<0.05$) nitrogen free extract than did the reference samples.

Proximate analysis of raw corn, masa, and WPC's used in this study are presented in Appendix E.

Amino acid composition and chemical score.

Nitrogen content, essential amino acid composition, and chemical scores for lysine and sulfur amino acids of freeze-dried corn gruels are shown in Table 15. Complete amino acid composition of corn gruels, raw corn, masa, and WPC's are presented in Appendixes F and G.

Table 15. Nitrogen content, essential amino acid content,[a] and chemical scores of freeze-dried corn gruels supplemented with WPC's,[b] and the 1973 FAO/WHO reference amino acid pattern.[c]

| Variable | Control | Masa: REG | Masa: PD | Masa: DELAC | FAO/ WHO |
|---|---|---|---|---|---|
| Nitrogen (%)[d] | 1.24 | 1.27 | 1.64 | 2.53 | --- |
| Essential amino acids (mg/g of protein) | | | | | |
| Histidine | 52.9 | 58.8 | 53.5 | 51.3 | --- |
| Isoleucine | 21.2 | 24.6 | 27.7 | 29.1 | 40 |
| Leucine | 112.5 | 106.0 | 106.8 | 111.3 | 70 |
| Lysine | 27.2 | 34.7 | 43.2 | 53.7 | 55 |
| Phenylalanine+tyrosine | 95.6 | 93.9 | 84.1 | 80.6 | 60 |
| Methionine+cystine | 39.9 | 39.1 | 31.5 | 38.9 | 35 |
| Threonine | 31.2 | 37.7 | 45.9 | 46.9 | 40 |
| Valine | 31.4 | 33.1 | 33.8 | 33.7 | 50 |
| Chemical score[e] | | | | | |
| Lysine | 49.4 | 63.1 | 78.5 | 97.6 | 100 |
| Methionine+cystine | 114.0 | 111.7 | 90.0 | 111.1 | 100 |

a, Results of one determination in one sample.
b, Supplementation level, 90:10 masa:WPC (by weight).
c, 1973 FAO/WHO provisional reference amino acid scoring pattern (FAO, 1973).
d, As determined by DIONEX Amino Acid Analysis System (DIONEX Chemical Corporation, Sunnyvale, CA).
e, Calculated as amino acid in test protein divided by amino acid in refernce pattern and multiplied by 100.

Chemical scores based on the amounts of lysine, sulfur amino acids, or tryptophan have been subjected to biological testing, since these are the amino acids found to be first limiting in most foods and diets. Therefore, in practice, for calculating the scores of ordinary food stuffs, only these three amino acids may need to be considered (FAO, 1973). In the present study, tryptophan was not measured because of its destruction during acid hydrolysis of the samples. Tryptophan content of the WPC used by Raccota and associates (1979) to supplement tortillas counteracted the tryptophan deficiency in tortilla.

The essential amino acid composition of unsupplemented corn gruels shows that, as in maize, lysine is the most limiting amino acid, with a chemical score of 49.4% of the FAO/WHO 1973 reference amino acid pattern (Table 15). Supplementation of corn gruels with WPC's improved scores for lysine. Lysine scores of corn gruels increased to 63.1, 78.5, and 97.6% as they were supplemented with REG WPC, PD WPC and, DELAC WPC respectively. Racotta and co-workers (1979) found that supplementation of tortilla with a heat coagulated WPC (54.7% protein) raised the level of essential amino acids to equal to or better than those of the FAO/WHO pattern in all cases, except lysine. Score for lysine in Racotta's study reached 75 and 88% when 25 and 35% of WPC were used, respectively.

The lowest score obtained for any of the essential amino acids (the most limiting amino acid) may be taken as a first approximation of the efficiency of utilization of the test protein or mixture by children and may indicate a needed correction of protein requirement to improve the quality of dietary protein (FAO, 1973). Isoleucine (score= 61.5%) was the most limiting amino acid for corn gruels supplemented with REG WPC, while for gruels supplemented with PD or DELAC WPC's, valine presented the lowest scores (67.6 and 67.4 respectively)(Appendix H) . According to Aguilera and Kosikowski (1978), leucine, present in large amounts in corn, increases the requirements for valine or isoleucine. The same authors found lysine as the most limiting amino acid in extruded mixtures of corn meal:partially delactosed WPC (70:22 by weight). Hernandez and associates (1981) obtained a score for lysine of 55.0% in mixtures of 90% (by weight) lime-treated corn flour and 10% dehydrated cheese whey (12.41% protein, 73.98 lactose). However, when the proportions of corn flour:dehydrated whey were changed so 50% of the protein was derived from each source, they found sulfur amino acids to be the most limiting ones. In our study, scores for sulfur amino acids for all treatments exceeded 100%, except for gruels supplemented with PD WPC (90%) (Table 15). Lower methionine content of PD WPC (6.7 mg/g of protein) as compared with REG (21.2mg/g of protein) and DELAC WPC (21.5 mg/g of protein) may be the reason for the lower score for sulfur amino acids in gruels supplemented with PD WPC (Appendix G).

In general, examination of the amino acid patterns of the gruels and their comparison to the FAO/WHO pattern assures a significant improvement in the nutritional value of corn gruels by the addition of WPC's. However, as changes in amino acid availability may occur with little changes in amino acid composition as determined by chemical methods, the use of biological tests for protein quality continues to be necessary. Sufficient biological evidence that whey protein is of an excellent quality, even superior to casein, and can be used to supplement adequately cereals, has been published elsewhere ( Womack and Vaughan, 1972; 1974; Forsum, 1975; Chan et al., 1976; Aguilera and Kosikowski, 1978; Racotta et al., 1979; Hernandez et al., 1981).

Energy values.

The energy values of corn gruels as calculated from proximate analysis are presented in Table 16. The difference ($p<0.001$) in protein content (Table 13) among the different gruels apparently did not affect their caloric values (Table 16). Probably the slight differences in fat content, together with the differences in carbohydrate content (Table 13) among the gruels, balanced the estimated caloric values for all treatments (Table 16).

Table 16. Calculated caloric values and lactose content of corn gruels supplemented with WPC's*.

| Treatment | Kcal/100g [a] | Lactose (%) [b] |
|---|---|---|
| Control | 397 | --- |
| Masa:REG WPC | 394 | 7.6 |
| Masa:PD WPC | 396 | 5.3 |
| Masa:DELAC WPC | 396 | 0.12 |

*, Supplementation level, 90:10 masa:WPC (by weight).
a, Calculated from proximate analysis of means of 6 replicates
b, Calculated from lactose content of WPC's reported by respective manufacturer.

Based on the FAO caloric allowances for preschool children (FAO/WHO, 1973), 250g corn gruels (one portion) provide approximately 72% of the allowance for 1-3 year old children and 54% of the allowance for children 4-6 years old. Young children fed corn gruels or porridges for long periods of time develop kwashiorkor (Williams, 1935). Kwashiorkor, a severe form of protein-caloric malnutrition (PCM), is charaterised by an adequate intake of calories with deficiency of proteins. Therefore, for efficient treatment of kwashiorkor, high quality protein is needed without increase in energy intake (Williams, 1935).

One hundred grams of corn gruels supplemented with WPC would provide approximately 30% of the NAS/NCR's RDA (1990) for energy for a 1- to 3-year old child. The same amount of gruel supplemented with REG, FD, or DELAC WPC would provide 44, 52, or 81% of the RDA for protein for a 1- to 3-year-old child, respectively. The USDA-AID-National Institutes of Health guidelines for nutrient composition of formulated foods for child feeding in the developing countries suggest that 100g of formulated food would supply at least one third of the calories and two-thirds of the RDA for protein for a 1- to 3-year old child (Senti, 1969).

Lactose content.

In milk and other dairy products such as whey, lactose content could be a limiting factor when they are used to supplement cereal products aimed at populations in developing countries (Aguilera and Kosikowski, 1978). Lactose content of corn gruels, as calculated from amounts of WPC added and lactose content of WPC's reported by their manufacturers, are 7.6, 5.3 and 0.12% for gruels supplemented with REG WPC, FD WPC, and DELAC WPC, respectively, (Table 16). The advantage of DELAC WPC over the other two WPC's as supplement for corn gruels is obvious, considering that 50% of the population of developing countries is lactose intolerant by the age of three years (Paige et al., 1975). Hernandez and associates (1981) found that a diet in which dehydrated cheese whey (73.98% lactose) furnished all the protein produced mild diarrhea in rats; however, this did not happen with any of the mixtures of lime-treated corn flour and dehydrated cheese whey. Womack and Vaughan (1974) found that rats fed a mixture of dried whey (29.8% lactose) and corn grits (50:50 protein basis) had some diarrhea; however, in the majority of cases this stopped after about a week. Despite the diarrhea, supplementation with even this crude preparation had positive effects on the growth of malnourished rats.

One portion (250g) of corn gruel supplemented with REG WPC, PD WPC, or DELAC WPC will contain 19.0, 13.25, or 0.3g of lactose, respectively. Therefore, a child of 1-3 years of age (13.4 Kg average body weight) (FAO/WHO, 1973) eating one portion would have an intake of 1.37, 0.99, or 0.02g of lactose /Kg body weight, respectively, at one time. A 4-6 year old child (20.2 Kg average body weight) would have a lactose intake of 0.94, 0.65, or 0.01g/Kg body weight when fed one portion of corn gruels supplemented with REG WPC, PD WPC, or DELAC WPC, respectively. Paige et al. (1972) found that symptoms of intolerance in lactose malabsorbers were present with 0.5g lactose/Kg body weight, but were more forceful and appeared earlier with lactose intakes of 2.0g/Kg. Many developing countries receive dry skim milk to be used as a protein supplement. The amount consumed usually does not exceed 200ml at one time. Reddy and Pershad (1972) believe that even a child with lactose intolerance is unlikely to develop symptoms with this supplement level. Considering that the presence of some lactose in the diet enhances absorption of minerals (Duncan, 1955), supplementation of corn gruels with REG WPC or PD WPC would be advantageous, providing that such intakes of lactose could be tolerated.

## SUMMARY

The present research was conducted in two parts: (1) Preliminary study on development of standard formula for corn gruels and selection of level of WPC supplementation, and (2) Major study on sensory evaluation, objective measurements, and nutritional quality of corn gruels supplemented with three different WPC's.

In the preliminary study corn gruels were prepared with lime-treated corn (masa), sucrose, salt, and water, and supplemented with 10, 15, 20, or 25g of WPC. The three WPC's used in the study were classified according to their lactose and protein contents as Regular (REG) (12% protein, 76% lactose), Partially Delactosed (PD) (35.7% protein, 53.0% lactose), and Delactosed (DELAC) (79.9% protein, 1.2%

lactose). Six trained judges compared color, masa aroma, masa flavor, consistency, and texture of the different combinations of each WPC separately, using unsupplemented corn gruels as reference. Data were analyzed by Analysis of Variance (AOV). When F-values indicated significant differences, least significant differences (LSD) among means were calculated. Among the different combinations tested, gruels supplemented with 10g WPC were selected to be used in the major study.

For the major study the same sensory panel compared the organoleptic characteristics of corn gruels supplemented with different WPC's. The objective measurements taken of the gruels included pH and spectrophotometric measurements. L-, a-, and b-values, together with percentage reflectance at 520 nm were determined in a HunterLab spectrophotometer. Data from sensory evaluation and objective measurements were analyzed by AOV and LSD procedures.

Evaluation of nutritional quality of corn gruels supplemented with WPC's included proximate analysess, and amino acid analyses. Chemical scores for lysine and sulfur amino acids were calculated using the 1973 FAO amino acid pattern as reference. Caloric values, estimated from proximate analysis, and lactose content, estimated from lacotse content of WPC's as reported by the manufacturers, also were examined.

Corn gruels supplemented DELAC WPC had less masa aroma and lighter color than did gruels supplemented with the other two WPC's. However, when overall scores were calculated, by adding the absolute values of all sensory scores, no significant difference among all gruels was found.

Results of spectrophotometric measurements indicated that supplementation with WPC's gave lighter products. Gruels supplemented with REG WPC were yellower, gruels supplemented with DELAC WPC were creamier, and products containing PD WPC were not significantly different in yellowness from the reference samples. pH measurements indicated that supplementation with REG WPC or DELAC WPC resulted in products with lower pH, while addition of PD WPC did not affected the pH of corn gruels.

No significant differences in moisture, ether extract, and fiber contents were found as result of supplementation with WPC's. Supplementaton with REG WPC increased the ash content of corn gruels. Protein content of supplemented corn gruels was higher than in plain corn gruels. Protein content increased according to the different levels of protein in the three WPC's utilized in the study. Carbohydrate content (expressed as nitrogen free extract) of supplemented corn gruels was lower than in the reference sample. Supplementation with DELAC WPC resulted in gruels with lower nitrogen free extract than gruels supplemented with the other two WPC's, but no difference in carbohydrate content between gruels supplemented with REG WPC and gruels supplemented with PD WPC was found. Chemical scores for lysine were increased as a result of the supplementation of corn gruels with WPC's, but only gruels containing DELAC WPC reached a lysine score higher than 90% of the FAO reference amino acid pattern. Scores for sulfur amino acids of supplemented gruels were higher than 100%, except for gruels supplemented with PD WPC (90%). Isoleucine was the most limiting amino acid in corn gruels supplemented with REG WPC, while in gruels supplemented with PD or DELAC WPC's, valine was the most limiting. Estimated energy values for all treatments were similar to those for the reference sample. One portion (250 g) of supplemented corn gruels will provide 72% of the caloric allowance for 1-3 year old children and 54% of the allowance for children of 4-6 years.

One- to three-year old children would have lactose intakes of 1.37, 0.99, or 0.02g/Kg body weight when fed one portion of corn gruels supplemented with REG, PD, or DELAC WPC, respectively; while 0.94, 0.65, or 0.01g/kg, in the same order, would be the lactose intakes for a 4-6 year old child.

# CONCLUSIONS

Under the conditions of this study, it was concluded that:

1) No differences in overall sensory scores were found among corn gruels supplemented with 10, 15, 20, or 25 g of DELAC WPC. Gruels supplemented with 10 g of REG or PD WPC were less different from the reference sample (100% masa) than were gruels supplemented with 15, 20, or 25 g of the same WPC's.

2) Addition of REG, PD, or DELAC WPC to corn gruels at 90:10 masa:WPC (by weight), gave no significant differences in overall sensory scores. Supplementation of corn gruels with DELAC WPC gave products lighter in color and with less masa aroma than gruels supplemented with REG or PD WPC.

3) Base on objective measurements,the use of WPC's to supplement corn gruels gave lighter products, but did not affect moisture, ether extract, or fiber contents. Addition of REG WPC increased ash content of corn gruels.

4) Supplementation with WPC's increased protein content of corn gruels; DELAC WPC gave the highest protein content and REG WPC, the lowest. Supplementation increased lysine content, but only gruels supplemented with DELAC WPC had a

lysine score higher than 90% of the FAO/WHO amino acid pattern. The most limiting amino acids were isoleucine (for REG WPC) and valine (for DELAC and PD WPC's).

5) Supplemented and unsupplemented corn gruels had similar caloric values. One portion (250g) of supplemented corn gruels would provide 54 to 72% of the caloric require= ments for pre-school children and lactose intakes in the range of 0.01 to 1.37 g/kg body weight.

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# VITA

Clark Eduardo Mac Donald was born in Ciudad de Guatemala, Guatemala, on February 7, 1959. He received his Bachelor of Science degree in Nutrition from Instituto de Nutricion de Centro America y Panama (INCAP)/Universidad de San Carlos de Guatemala. Following 10 months of tutorial work at the Food Science and Agriculture Division of INCAP under guidance of Dr. L. G. Elias, Dr. R. Bressani, and Dr. E. Braham, he attended Kansas State University, Manhattan, Kansas, where he pursued the Master of Science degree in Food Science. During that time he held a graduate research assistantship.

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He is married to Beverley Rowley Mac Donald.

APPENDIX

# APPENDIX A

## PROCEDURE FOR PREPARATION OF CORN GRUELS

1. Place masa an WPC in a stainless steel cooking pot. Add water, sugar, and salt. Stir well with a wooden spoon.

2. Cook the mixture over "medium" heat until it reaches 85 $^{o}$C, stirring constantly to avoid lumps.

3. Lower the heat to "low" and cook for 5 minutes stirring constantly.

4. The formula showed in Table 5 provides one and one half servings of 250 ml. of gruel.

# APPENDIX B

## EXAMPLE OF SCORE CARD USED IN SENSORY EVALUATIONS

### QUESTIONNAIRE FOR AROMA

DATE___________ JUDGE No.__

| Number of the sample set | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| sample codes | | | | | | | | | | | | |
| More masa aroma than R | | | | | | | | | | | | |
| Equal masa aroma to R | | | | | | | | | | | | |
| Less masa aroma than R | | | | | | | | | | | | |
| AMOUNT OF DIFFERENCE | | | | | | | | | | | | |
| None | | | | | | | | | | | | |
| Barely | | | | | | | | | | | | |
| Slight | | | | | | | | | | | | |
| Moderate | | | | | | | | | | | | |
| Extreme | | | | | | | | | | | | |

COMMENTS:

# APPENDIX C

## 11-POINT SCALE FOR SENSORY SCORES

### MASA AROMA/MASA FLAVOR

| | | | | | | |
|---|---|---|---|---|---|---|
| Extremely | more | masa | aroma/flavor | than | R | = +5 |
| Much | " | " | " " | " | " | = +4 |
| Moderately | " | " | " " | " | " | = +3 |
| Slightly | " | " | " " | " | " | = +2 |
| Barely | " | " | " " | " | " | = +1 |
| Equal | | masa | aroma/flavor | to | R | = 0 |
| Barely | less | masa/flavor | aroma | than | R | = -1 |
| Slightly | " | " " | " " | " | " | = -2 |
| Moderately | " | " " | " " | " | " | = -3 |
| Much | " | " " | " " | " | " | = -4 |
| Extremely | " | " " | " " | " | " | = -5 |

### CONSISTENCY

| | | |
|---|---|---|
| thicker than R = +5 | Extremely | thinner than R = -5 |
| " " " = +4 | Much | " " " = -4 |
| " " " = +3 | Moderately | " " " = -3 |
| " " " = +2 | Slightly | " " " = -2 |
| " " " = +1 | Barely | " " " = -1 |
| | Equal to R = 0 | |

### TEXTURE

| | | |
|---|---|---|
| smoother than R = +5 | Extremely | less smooth than R = -5 |
| " " " = +4 | Much | " " " " = -4 |
| " " " = +3 | Moderately | " " " " = -3 |
| " " " = +2 | Slightly | " " " " = -2 |
| " " " = +1 | Barely | " " " " = -1 |
| | Equal to R = 0 | |

### COLOR

| | | |
|---|---|---|
| lighter than R = +5 | Extremely | darker than R = -5 |
| " " " = +4 | Much | " " " = -4 |
| " " " = +3 | Moderately | " " " = -3 |
| " " " = +2 | Slightly | " " " = -2 |
| " " " = +1 | Barely | " " " = -1 |
| | Equal to R = 0 | |

# APPENDIX D

## PRELIMINARY WORK TO DETERMINE SPECTROPHOTOMETRIC MEASUREMENTS OF CORN GRUELS THAT BEST DESCRIBE THEIR COLOR

### Methods

Corn gruels with 0, 10, 25, and 50% WPC were prepared. One tablespoonful of gruel was cooled to room temperature ($23^{o}C$), and placed in an optically clear cup (6 cm. in diameter) for measurement in a HunterLab spectrophotometer (model D54P-5, Hunter Associated Laboratory, Reston, VA). Four replicate samples were used, and four spectrophotometric readings, rotating the cup $90^{o}$ each time, were taken; the means of four readings were recorded. Measurements of L-, a-, and b- values, together with percent reflectance every 10 nanometers (nm), were taken. The parameters Theta ( Θ ), and Saturation Index (SI) were calculated using the following formulas:

$$\Theta = Tang^{-1} (b/a)$$

$$SI = \sqrt{a^2 + b^2}$$

Data on L-values, Θ, and SI were subjected to Principal Component Analysis (Morrison, 1976). Data from Percentage Reflectance (%R) were ploted against WPC concentration to look for the wavelength that gave the most linear relationship.

## Results

The Principal Components Score for the different WPC's were:

$$Prin1Score_{REG} = (0.890290)(L)-(0.004854)(D)-(0.455367)(SI)$$

$$Prin1Score_{DELAC} = (0.949517)(L)-(0.001365)(D)-(0.313713)(SI)$$

$$Prin1Score_{PD} = (0.990224)(L)+(0.0031610)(D)+(0.139441)(SI)$$

The results of the Principal Component Analysis indicated that the best spectrophotometric measurements to describe the color of gruels were L- value and SI, and, therefore, they were selected to be used in the major study. However, gruels supplemented with 10g WPC used in the major study gave low a-values, thus, the calculated values for SI were very similar to b-values. Therefore, L-, a-, and b-values were selected as the spectrophotometric measurements to be used in the major study. Data on %R at different wavelength ploted against concentrattion of WPC used indicated that values at 520 nm had a more linear relationship and larger differences in the amount of light reflected by samples of the treatments studied; therefore, 520 nm was selected as the wavelength to be used in the major study.

# APPENDIX E

## PROXIMATE ANALYSIS AND pH OF RAW MATERIALS

| | CORN[a] | MASA[b] | REG WPC[c] | PD WPC[c] | DELAC WPC[c] |
|---|---|---|---|---|---|
| Moisture (%) | 11.60 | 48.5 | 5.0 | 3.5 | 4.0 |
| Ash (%) | 1.53 | 1.2 | - | 6.0 | 4.0 |
| Nitrogen (mg/gm) | 17.85 | 10.7 | - | - | - |
| Crude Protein (%) | 11.15 | 6.7 | 12.0 | 35.7d | 79.7d |
| Ether Extract (%) | 4.80 | 4.9 | 1.25 | 2.5 | 4.5 |
| Crude Fiber (%) | 2.45 | 1.4 | - | - | - |
| Nitrogen Free Extract(%) | 80.15 | 85.9 | - | - | - |
| Lactose | - | - | 12.0 | 53.0 | 1.2 |
| Other Carbohydrates | - | - | - | - | 9.8 |
| pH (10% sol. 20 $^{o}$C) | | | 6.00 | 7.18 | 6.18 |

a, Average of 2 replications.
b, Average of 6 replecations.
c, as reported by manufacturers.
d, dry basis.

# APPENDIX F

## COMPLETE AMINO ACID COMPOSITION OF FREEZE-DRIED CORN GRUELS[a] SUPPLEMENTED WITH WPC'S.[b]

| AMINO ACID (mg/g prot) | CONTROL[c] | MASA:REG | MASA:PD | MASA:DELAC |
|---|---|---|---|---|
| Aspartic Acid | 69.2 | 73.4 | 98.8 | 96.0 |
| Threonine | 31.2 | 37.7 | 45.9 | 46.9 |
| Serine | 49.7 | 49.4 | 53.2 | 50.8 |
| Glutamic Acid | 180.2 | 172.9 | 172.6 | 171.7 |
| Proline | 79.9 | 75.3 | 76.4 | 68.7 |
| Glycine | 39.2 | 35.9 | 31.9 | 29.3 |
| Alanine | 75.6 | 76.6 | 67.1 | 64.5 |
| Half Cystine | 15.1 | 14.0 | 14.7 | 15.9 |
| Valine | 31.4 | 33.1 | 33.8 | 33.7 |
| Methionine | 24.8 | 25.1 | 16.8 | 23.0 |
| Isoleucine | 21.2 | 24.6 | 27.7 | 29.1 |
| Leucine | 112.5 | 106.0 | 106.8 | 111.3 |
| Tyrosine | 45.5 | 43.9 | 39.0 | 38.6 |
| Phenylalanine | 50.1 | 50.0 | 45.1 | 42.0 |
| Hystidine | 52.9 | 58.9 | 53.5 | 51.3 |
| Lysine | 27.2 | 34.7 | 43.2 | 53.7 |
| Arginine | 63.8 | 61.2 | 57.2 | 51.3 |

a, Results of one single sample by DIONEX Amino Acid Analysis System (DIONEX Chemical Corporation, Sunnyvale, CA).
b, Supplementation level masa:WPC, 90:10 by weight.
c, 100% Masa.

# APPENDIX G

COMPLETE AMINO ACID COMPOSITION[a] OF MASA AND RAW MATERIALS.

| AMINO ACID (mg/g prot) | CORN | MASA[b] | REG WPC | PD WPC | DELAC WPC |
|---|---|---|---|---|---|
| Aspartic Acid | 73.2 | 68.5 | 111.8 | 118.3 | 117.8 |
| Threonine | 33.7 | 31.2 | 65.2 | 68.1 | 57.2 |
| Serine | 51.0 | 50.3 | 55.1 | 56.4 | 52.4 |
| Glutamic Acid | 172.3 | 179.5 | 158.1 | 166.4 | 165.7 |
| Proline | 81.6 | 85.4 | 59.4 | 61.0 | 56.0 |
| Glycine | 40.2 | 38.8 | 22.5 | 21.2 | 21.5 |
| Alanine | 75.8 | 78.2 | 49.2 | 50.8 | 54.4 |
| Half Cystine | 14.3 | 14.6 | 14.8 | 15.8 | 17.4 |
| Valine | 32.7 | 32.1 | 37.7 | 38.9 | 35.8 |
| Methionine | 24.4 | 26.0 | 21.2 | 6.7 | 21.5 |
| Isoleucine | 22.3 | 22.1 | 37.6 | 39.1 | 35.0 |
| Leucine | 108.8 | 118.8 | 89.6 | 93.3 | 108.1 |
| Tyrosine | 45.2 | 46.3 | 32.6 | 32.4 | 35.4 |
| Phenylalanine | 51.3 | 51.7 | 40.2 | 38.9 | 37.2 |
| Hystidine | 53.2 | 47.6 | 55.5 | 46.5 | 54.7 |
| Lysine | 30.3 | 24.7 | 77.5 | 79.8 | 81.2 |
| Arginine | 62.6 | 51.0 | 42.3 | 43.0 | 32.2 |

a, Results of one determination in one single sample by DIONEX Amino Acid Analysis System (DIONEX Chemical Corporation, Sunnyvale, CA).

b, Freeze-dried.

# APPENDIX H

## SCORES FOR MOST LIMITING AMINO ACIDS OF FREZE-DRIED CORN GRUELS SUPPLEMENTED WITH WPC's[a]

$$\text{Score} = \frac{\text{mg of amino acid/g test protein}^{b}}{\text{mg of amino acid/g reference protein}^{c}} \times 100$$

$$\text{CONTROL} = \text{Lysine Score} = \frac{27.2}{55.0} \times 100 = 49.4$$

$$\text{Masa:REG} = \text{Isoleucine Score} = \frac{24.6}{40.0} \times 100 = 61.5$$

$$\text{Masa:PD} = \text{Valine Score} = \frac{33.8}{50.0} \times 100 = 67.6$$

$$\text{Masa:DELAC} = \text{Valine Score} = \frac{33.7}{50.0} \times 100 = 67.4$$

a, Supplementation level Masa:WPC, 90:10 by weight.
b, As determine by DIONEX Amino Acid Analysis System (DIONEX Chemical Corporation, Sunnyvale, CA).
c, 1973 FAO/WHO provisional reference amino acid scoring pattern (FAO/WHO, 1973).

# SUPPLEMENTATION OF CORN GRUELS WITH WHEY PROTEIN CONCENTRATES FOR PRE-SCHOOL CHILD FEEDING IN GUATEMALA

by

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B.Sc., Universidad de San Carlos de Guatemala, 1981

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Recently, numerous studies have shown that whey protein concentrates (WPC's) represent a protein source with considerable potential for blending with cereals to improve their nutritional properties. The objective of this research was to obtain basic data that could be applied to the production of a protein-rich food mixture for Guatemalan preschool children.

In the preliminary study corn gruels were prepared with lime-treated corn (masa), sucrose, salt, and water, and supplemented with 10, 15, 20, or 25g of WPC. The three WPC's used in the study were classified according to their lactose and protein contents, as Regular (REG) (12% protein, 76% lactose), Partially Delactosed (PD) (35.7% protein, 53.0% lactose), and Delactosed (DELAC) (79.9% protein, 1.2% lactose). Among the different combinations evaluated by six trained judges, gruels supplemented with 10g WPC were selected to be used in the major study.

In the major study organoleptic characteristics, objective measurements, and nutritional quality of corn gruels supplemented with different WPC's were compared. Data were analyzed by Analysis of Variance.

Corn gruels supplemented DELAC WPC had less masa aroma and lighter color than did gruels supplemented with the other two WPC's. However, when overall scores were calcu-

lated, by adding the absolute values of all sensory scores, no significant difference among all gruels was found.

Results of spectrophotometric measurements indicated that supplementation with WPC's gave lighter products. Gruels supplemented with REG WPC were yellower, gruels supplemented with DELAC WPC were creamier, and products containing FD WPC were not significantly different in yellowness from the reference samples. pH measurements indicated that supplementation with REG WPC or DELAC WPC resulted in products with lower pH, while addition of FD WPC did not affect the pH of corn gruels. Supplementaton with REG WPC increased the ash content of corn gruels. Protein content of supplemented corn gruels increased according to the different levels of protein in the three WPC's utilized in the study. Carbohydrate content of supplemented corn gruels was lower than in the reference sample. Supplementation with DELAC WPC resulted in gruels with lower carbohydrate content than gruels supplemented with the other two WPC's. Chemical scores for lysine were increased as a result of the supplementation of corn gruels with WPC's, but only gruels containing DELAC WPC reached a lysine score higher than 90% of the FAO reference amino acid pattern. Calculated energy values for all treatments were similar to those for the reference sample. Lactose intakes of pre-school children fed WPC-corn gruels were calculated.