PROTEIN ENRICHMENT AND EFFECTS ON THE SENSORY AND OBJECTIVE QUALITIES OF VENEZUELAN AREPAS

By

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CHAPTER I

INTRODUCTION

As the world's population expands, the problem of supplying quantity and quality of protein foods increases. According to the latest United Nations projections, the world population could rise from nearly 4.0 billion in 1975 to 6.3 billion by the year 2,000 (Food and Agriculture Organization (FAO), 1983). More and more attention is being focused on vegetable sources of high quality protein, which are cheaper than animal protein, to alleviate protein malnutrition in the world.

In developing countries, two-thirds of the daily protein intake is derived from a cereal or starch staple such as wheat, rice, corn, barley, rye, millet, oats, sorghum, cassava, or plantain. These sources usually do not supply adequate protein and are deficient in one or more of the essential amino acids which are necessary in specific amounts and proportions to provide synthesis of protein. Improving the protein quality and quantity of plant foods, therefore, is one of the most important short-term approaches to combating protein malnutrition.

Corn is a cereal staple in Mexico, Nicaragua, El Salvador, Costa Rica, Guatemala, Honduras, Bolivia, Colombia, Venezuela and some countries of Africa. Daily consumption of corn in Venezuela is 120-350 grams per capita (Bressani, 1972). A flour prepared commercially from corn is used in various bread products such as "arepas," "hallaquitas," or "funche." Arepas, which are small breads composed of corn flour, water, and salt, are eaten two or three times daily by 90 percent of the Venezuelan population. Arepas also are widely eaten in Colombia and Bolivia. In Colombia, approximately one-third of the total calorie intake is from arepas (Pradilla, 1972).

Dependence on corn is increasing since animal proteins are in short supply and too expensive for the common people. Although arepas are a good caloric source, the protein content is low, 3.95-5.50 percent (Alvarez, 1981) and of poor quality due to low concentrations of lysine, tryptophan, and threonine in corn flour. Under these circumstances, it is desirable to improve both the quality and the quantity of the protein in the flour used to prepare staple bread arepas by adding a protein high in those amino acids. Some studies have been done to increase the protein of food systems made from corn (such as tortillas, beverages, or porridges) by the addition of legumes, yeast, cottonseed flour, or soybean flour to corn protein (Bressani, 1965; Scrimshaw, Bressani, Wilson, and Behar, 1962; Gilbert and Gillman, 1959).

Legumes, which contain lysine and tryptophan, are extensively used in Venezuela. Beans are the most popular legume, and since they are locally grown, they can improve the amino acid profile of arepas at minimum cost. Amaranth, a high protein grain that grows wild across South America, can be ground to a flour that could supplement the protein of corn because of its high content of essential amino acids (Senft, 1980). Dried yeast cells are also a source of very high-quality protein and could be used to improve the protein content of arepas.

Such protein-enriched arepas would be of special benefit to rapidly growing school children in the lower income groups, for pregnant and lactating women, and for infants and young children during and after weaning. These population groups have a higher than usual protein requirement, and since commercial diets and weaning foods tend to be costly, it is imperative that inexpensive but high quality foods be developed for these groups.

Purpose and Objectives

The purpose in this research is to increase the protein level and improve the amino acid content of corn arepas (when comparing to the FAO pattern) by substituting bean flour, amaranth flour, and yeast in five different formulas for part of the corn flour and to determine the effects these substitutions have on the subjective and objective qualities of arepas. Subjective qualities include appearance, texture, color, flavor, mouthfeel, and overall acceptability. Objective qualities include tenderness, specific volume, moisture content, protein content, and amino acid profile. Specific objectives of the study are:

1. To identify the effects of the following five formulas on the sensory and objective qualities of arepas.

Formula 1

78 percent corn flour
20 percent bean flour
2 percent yeast flour

Formula 2

78 percent corn flour
10 percent bean flour

10 percent amaranth flour

2 percent yeast flour

Formula 3

60 percent corn flour

30 percent bean flour

10 percent yeast flour

Formula 4

50 percent corn flour

30 percent bean flour

10 percent amaranth flour

10 percent yeast flour

Formula 5 (Control or standard arepa)

100 percent corn flour

2. To make recommendations in this field for future research.

Hypotheses

The hypotheses postulated for this research were:

H_1: There will be no significant differences among the five formulas mentioned associated with subjective qualities of arepas. Subjective qualities include appearance, flavor, interior color, crust color, interior texture, crust texture, mouthfeel, and overall acceptability.

H_2: There will be no significant differences among the five formulas mentioned associated with objective qualities of arepas. Objective qualities include tenderness, specific volume, moisture content, protein content and amino acid profile.

Assumptions

The assumptions made for this research were:

1. A taste panel of Venezuelan students at Oklahoma State University will judge the products objectively as instructed.

2. The only difference among the experimental products, all prepared in the same food research laboratory under controlled conditions, will be the result of the formula used.

Limitations

The limitations accepted in this research were:

1. The corn flour used in this study was the white variety obtained from Productos Milpa C.A. Guacara, Estado Carabobo, Venezuela.

2. The amaranth flour used in this study was the variety *hypochondriacus*, type R103, obtained from Walnut Acres, Organic Farming and Natural Foods, Penss Creek, Pennsylvania 17862.

3. The only yeast used (Provesteen) was obtained from Provesta Corporation, a subsidiary of Phillips Petroleum Company, Bartlesville, Oklahoma.

4. Navy beans were obtained from the local market.

5. Only baked arepas were used for testing the enriched formulas.

Definitions

The following terms were important to this research:

Arepa: National bread of Venezuela. An unleavened bread made of corn, kneaded with salt and water, shaped into a flat disc (about 3/4 inches thick and 3-4 inches in diameter) and either fried or griddled/baked until golden brown.

Corn flour: Flour used to make arepas. Prepared from white corn grains that are decorticated by soaking or steeping; boiled slowly until tender but not soft; cooled and rinsed, then ground. Product may be made into arepas at this point or dried to form a reconstituitable arepa flour. The flour is similar in appearance to corn grits.

Amaranth flour: A finely ground or milled mature grain (seeds) of Amaranth hybrids, specifically _Amaranthus hypochondriacus_ or _A. cruentus_.

Single cell protein (SCP): Refers to the dried cells of microorganisms such as algae, actinomycetes, bacteria, yeast, molds, and higher fungi grown in large-scale culture systems for use as a protein source in human foods or animal feeds (Litchfield, 1983).

Amino Acid: The building block of protein; a compound containing an amino group and an acid group attached to a central carbon, which also carries a distinctive R-group (Whitney and Hamilton, 1981).

Essential Amino Acid: An amino acid that the body cannot synthesize in amounts sufficient to meet physiological needs, and therefore must be supplied by the proteins of the diet. The eight amino acids known to be essential for human adults are: methionine, threonine, tryptophan, isoleucine, leucine, lysine, valine, and phenylalanine (Robinson, 1977).

Limiting Amino Acid: The amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body (Whitney and Hamilton, 1981).

Texture: In foods, the characteristic consistency and overall structure. Includes hardness, cohesiveness, viscosity, and elasticity (Paul and Palmer, 1972).

Color: Determination of hue, purity, and lightness which correlates well with human perception of color (Noble, 1975).

Flavor: A complex sensation with taste, aroma, and mouthfeel as the three categories or components (Amerine, Pangborn and Roessler, 1965).

Mouthfeel: A mingled experience derived from the sensations of the skin in the mouth during and after ingestion of a food or beverage that relates to density, vicosity, surface tension, and other physical and chemical properties of the material being sampled (Amerine, Pangborn, and Roessler, 1965).

Protein Efficiency Ratio (PER): Gain in body weight divided by weight of protein consumed (FAO, 1970).

CHAPTER II

REVIEW OF LITERATURE

Although much of the world's population does not have adequate protein intake, quality of proteins as well as quantity is important. Many protein sources are limited in the amount of various amino acids and must be complemented by other proteins in order to be complete. Among sources of protein that could be complementary to corn are single cell proteins, legumes, and amaranth. This chapter presents selected literature relating to the limiting amino acid concept and its importance in improving protein quality and quantity. Literature concerning corn arepas has been reviewed as well as the use of single cell proteins, legumes, and amaranth as protein supplements in food systems.

Limiting Amino Acid and Its Importance

Several countries have investigated the use of low cost, commonly consumed but high quality foods prepared from inexpensive local plant sources to bridge the world's protein gap. Quality can be improved by blending protein sources into an improved pattern of amino acids that maximizes efficiency of utilization. If a protein has a low concentration of one or more essential amino acids, the efficiency of utilization of all the other amino acids is limited by the one present in the lowest amount; and if a single essential amino acid is missing, vital proteins cannot be synthesized, resulting in impaired growth or death of the organism (Bressani, Elias, and Gomez-Brenes, 1972). Deficiencies limit the development of the living system. Requirements vary according to the living system (man or animal) and to the function being measured in that system, whether growth, maintenance, or repletion of depleted tissues. If a protein, therefore, meets the minimum needs of the living system, it can be called a high quality protein, or a protein with high biological value (Bressani et al., 1972).

The decision whether an amino acid is or is not deficient and its order of limitation depends on the pattern used as a reference. Patterns have been established for animals; for humans, amino acid requirements are not well known, although the amino acid pattern of the egg has been used (Beaton and Patwardham, 1976). The first limiting amino acid can be defined as the amino acid present in the smallest amount in comparison with the reference concentration (Beaton et al., 1976). When improving the amino acid pattern of a protein, the first limiting amino acid should be added in such an amount that the total of this amino acid in the protein of the diet balances with the amount of the second limiting amino acid and the other components in accordance with the needs of the organism or the essential amino acid reference pattern (Bressani et al., 1972). The addition of an excess of the first limiting amino acid may result in a secondary deficiency and no improvement in the overall quality of the diet. Also, it can cause an increased vitamin requirement (Harper, 1974). Examples have been shown between methionine and pyridoxine, as well as leucine and nicotinic acid (Harper, 1974).

When the intake of animal protein foods falls below generally recommended levels, the percentage of protein derived from cereal food becomes larger. This is probably why most of the amino acid supplementation studies found in the literature have involved cereal grains.

Wheat, corn, rice, sorghum, millet, rye, and barley have been considered over the years as the most important sources of energy for man and animals (Lockhart and Nesheim, 1978). As is well known, cereals contain a relatively low protein concentration; therefore, because they are consumed in large quantities, the amount and quality of cereal protein is extremely important. Corn is an important staple food in many areas of the world, particularly in Latin American countries, hence there has been much interest in improving the nutritional value of corn protein by several means.

Means of Improving Protein Quality and Quantity

Amino acid deficiencies can be overcome by the addition of the appropriate amounts of the deficient amino acids either as the synthetic compounds or in proteins which are rich sources of the deficient amino acids (Bressani, 1974). The result in either case is increased protein quality because of the improved amino acid pattern, but when protein food is added, a higher protein content is also obtained. The deficient pattern of corn can be corrected by combining it with another protein whose amino acid pattern is complementary, so that each tends to make up the deficiency of the other, as has been shown by Bressani and Marenco (1963) and Sure (1948 and 1957).

Small amounts of defatted fish flour were used by Sure, Easterling, Dowell, and Grudup (1957) to demonstrate its value in the supplementation of wheat flour, corn meal, and rice. In experiments with rats, this investigator used fish flour at the levels of 1 percent, 3 percent, and 5 percent to supplement the protein of those cereals. The results showed that the 3 percent addition of fish flour was enough to increase the protein efficiency ratio (PER) to 132.4 percent in milled wheat flour and 64.3 percent in unpolished rice flour. No further increase in the PER of those cereals was obtained with the addition of 5 percent fish flour. In the case of corn meal, the addition of 5 percent fish flour produced an increase in the protein efficiency ratio of 484.4 percent, and was the optimum of the three levels of supplementation used.

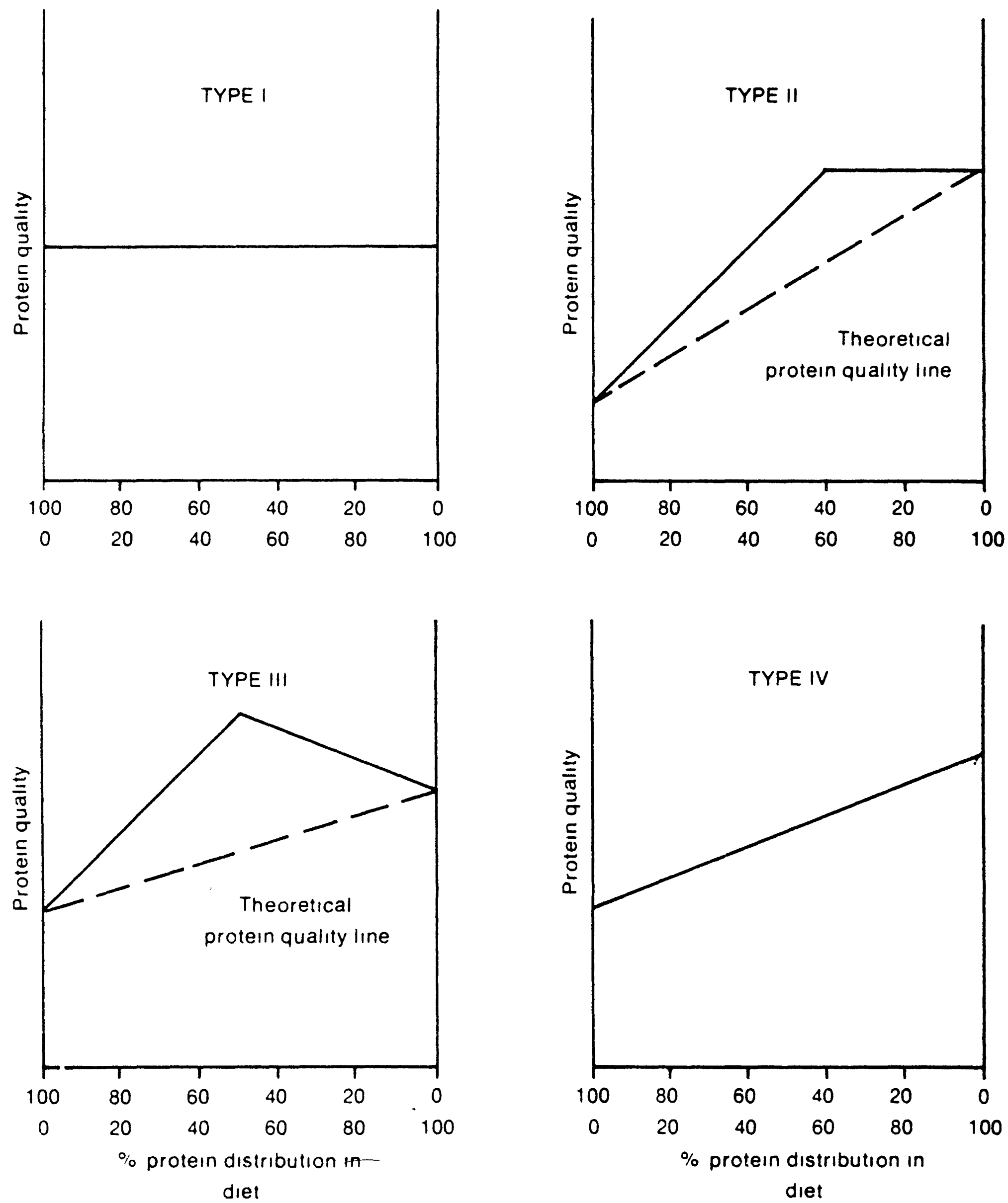
The nutritive value of tortillas made of lime-treated corn was significantly improved by adding one of the following quantities of protein-rich products; fish flour, 3 percent; meat flour, 5 percent; whole egg flour, 3 percent; casein, 5 percent; skim milk powder, 8 percent; soybean protein, 8 percent; soybean flour, 8 percent; cottonseed flour, 9 percent; and torula yeast, 3 percent (Bressani and Marenco, 1963). The improvement in the protein quality of lime-treated corn was higher with the animal products and yeast due to the contribution made by the supplements in providing lysine, tryptophan, and isoleucine--amino acids limiting the nutritive value of the protein of lime-treated corn. Those examples showed how a poor quality food became one of better nutritive value through the contribution of supplementary proteins.

Three methods can be used to improve amino acid balance in foods, however, protein complementation seemed to be the most effective (Bressani et al., 1972). Pure amino acid addition improves protein quality but does not materially increase protein quantity. On the other hand, protein supplementation increases both protein quality and quantity; but since the amounts of protein concentrate or isolate added are usually relatively small, the protein content in the final mixture increases only as the protein supplement is added.

Protein complementation seems to overcome these two problems. Once the best combination is found, the protein level can be raised, although the ratio of the two-mixed proteins is kept constant. In protein complementation, the method consists of mixing two proteins in a series of diets; one diet prepared exclusively with one protein and the other diet with a second one. The nitrogen of the first protein is progressively replaced by the nitrogen from the second one in such a way that all the combinations have the same protein content, usually 10 percent expressed as protein (Bressani and Elias, 1968). The response may be measured by any of the techniques used to measure protein quality such as NPU (nitrogen protein utilization), NB (nitrogen balance), or PER (protein efficiency ratio). Mixing two proteins by this technique, four types of response can be obtained (Bressani and Elias, 1968) (Figure 1).

Type I (Figure 1) is obtained when the two protein sources to be mixed have a common amino acid deficiency. The quality of such a mixture is the same throughout; no complementation occurs. An example of this is the combination between corn and peanuts. The common amino acid deficiency is lysine (Bressani, Elias, and Braham, 1968), and the higher amount of methionine in corn is not enough to correct the deficiency of this amino acid in peanut flour. In this situation the protein content of the mixture depends on the level of peanut flour used since it contains at least four times as much as corn; however, the quality of the protein in the mixture will be equal or similar to that of corn or of the peanut flour alone.

Type II (Figure 1) represents a combination of two protein foods with a common amino acid deficiency; however, one of the two proteins contains a higher level of the deficient amino acid than the second one.



Source: Bressani, 1974. Reprinted from Complementary amino acid patterns. In "Nutrients in Processed Foods. Proteins," p. 158

Figure 1. Types of Response Lines Obtained When Mixing Two Protein Sources

The relatively larger quantity of this amino acid in one of the proteins supplements the limiting amino acid of the other, but this beneficial effect is observed only to a certain point of the mixture. After this point, the protein quality value does not change. An example of this type of combination is the mixing of corn and cottonseed flour so that the lysine deficiency in the corn protein is partially corrected by the lysine content present in cottonseed flour, but this supply is not high enough to completely correct the deficiency in corn, resulting in a product with the quality of cottonseed flour (Bressani, Elias, Aguirre, and Scrimshaw, 1961).

Type III (Figure 1) represents a true complementation where the two ingredients to be mixed are able to correct the specific amino acid deficiency of each protein. The nutritive value of the mixture is higher than that for either component. Examples are mixtures of corn and beans (Bressani, Valiente, and Tejada, 1962; Bressani and Elias, 1969) soybeans and corn (Bressani, Elias, and Braham, 1966), and torula yeast and corn (Elias and Bressani, 1970), as reported in the literature reviewed by Bressani et al., 1972.

Type IV (Figure 1) is obtained when one of the proteins to be mixed has a higher protein value than the other, but they have a common amino acid deficiency, although in a different degree. A supplementation rather than a complementation is achieved. The biological value of the mixture is directly proportional to the addition of the ingredient with the best quality protein. The mechanisms by which these four types of response are obtained have not been fully understood. It is believed that the most important factors influencing the different protein mixtures are the content and proportion of essential amino acids and their availability.

Calculations based on the amino acid content of corn in comparison with reference patterns from egg or milk have indicated that lysine is first limiting in corn. Several authors have corroborated this by feeding trials as reported in the literature reviewed by Bressani et al (1972). Bressani, Elias, and Braham (1968) and Bressani and Marenco (1963), however, have concluded that the effect of pure lysine added to corn causes only a small improvement in protein quality. Some workers have reported that tryptophan rather than lysine is the first limiting amino acid in corn (Hogan, Gillispie, Kocturk, O'Dell, and Flynn, 1955), which can be true for some varieties with a high lysine concentration or corn products modified by some type of processing. The results on which all workers have agreed is that the addition of both lysine and tryptophan simultaneously improves protein quality of corn significantly, as demonstrated in experimental animals, adult males, and children (Bressani et al., 1972). Apparently the third limiting amino acid in corn is isoleucine, as determined from tests in humans (Scrimshaw, Bressani, Behar, and Viteri, 1958; Bressani, Scrimshaw, Behar, and Viteri, 1958; and Bressani, Wilson, Chung, Behar, and Scrimshaw, 1963). Most workers have found that the effect of an isoleucine addition is due to an excess of leucine which interferes in the absorption and utilization of isoleucine. It has been indicated that diets high in corn and thus high in leucine from corn protein increase niacin requirements, so leucine could be partially responsible for pellagra. When threonine is added, it has the effect of correcting amino acid imbalances caused by too much methionine (Bressani, 1963). Similarly, the addition of valine could be balanced by the addition of either isoleucine or threonine (Bressani, 1963), with isoleucine seeming to be more effective. A possible explanation for these findings is that corn is not deficient in either isoleucine or threonine; however, some samples of corn may contain larger amounts of leucine, methionine, and valine, and they require the addition of isoleucine and threonine, besides lysine and tryptophan, to improve the protein quality.

Studies made by Bressani and Elias (1966) of the complementary value of soybean and corn proteins led to the formulation of the INCAP (Institute of Nutrition of Central America and Panama) Vegetable Mixture 14 which consists of 58 percent corn flour, 38 percent soybean flour, 30 percent torula yeast, 1 percent calcium phosphate, and 4,500 International units vitamin A per 100 grams. This mixture contains approximately 27 percent protein. The NBI (nitrogen balance index) of this mixture is superior to that of the Vegetable Mixture 9 and very similar to that of casein. Vegetable Mixture 9 contains 28 percent lime-treated corn, 28 percent sorghum grain, 38 percent cottonseed flour, 3 percent kikuyu leaf meal, and 3 percent torula yeast (Bressani et al., 1962). This study showed that 56 percent of cereal in the corn and sorghum formula could be supplied equally by corn, sorghum, or any combination of the two. The also showed that ground rice, oats, and wheat may be substituted for the ground corn and sorghum in the basic formula without affecting nutritive value significantly.

Corn

Maize or corn (*Zea mays L*) is a native American plant belonging to the grass family of *Gramineae* within the tribe *Maydae*. Corn is a traditional crop in Venezuela. It has been the staple grain in this country, and corn arepas the main form of consumption. Traditionally, degermed hard field corn is soaked overnight in water at room temperature, simmered for about three hours, cooled, drained, and ground to a moist dough in a kitchen grinder, which is then rolled out and cut into flat discs (arepas) and either fried or baked, depending on the region of Venezuela. In 1954, commercial pre-cooked flour appeared and a similar dough is made by mixing it with water. Nutritional studies conducted over twenty years ago showed that the protein content of arepas was low (3.95-5.50 percent). In addition, vitamin B and niacin were also low (Suarez, 1954 and 1955). Suarez attributed the vitamin deficiency to the milling of corn, and tried supplementing arepas with vitamins B_1, B_2, niacin, and iron. He also investigated supplementing arepas with amino acids, and concluded that the addition of 0.2 percent L-tryptophane, 1.0 percent L-lysine, and 0.5 D-L-threonine increased arepa protein efficiency (Suarez, 1955). Chavez and Pellet (1976) determined protein quality of 12 different food mixtures eaten in Latin America using rat bioassay. Of the 12, five were different arepa preparations. These included arepa with meat, arepa with black bean, arepa with sardines, arepa with cheese, and arepa with margarine. The protein percents of the arepas were 22.0, 16.6, 22.8, 23.1, and 8.2 respectively. The protein efficiency ratios were 4.6, 2.9, 3.9, 3.8, and 0.5 respectively.

More recently, Alvarez (1981) reported proximate composition and biochemical changes during the production of baked and fried arepas. The results are shown in Table I.

Although arepas are a good source of calories, 168.4 Kcal/100 grams for baked arepas and 340.3 Kcal/100 grams for fried arepas, the protein content is rather low. Enrichment of the protein in arepas with minimum change in flavor and cost is important because of the tremendous consumption of arepas by Venezuelans.

TABLE I

PROXIMATE COMPOSITION OF BAKED AND FRIED AREPAS

		Baked	Fried
Moisture[a]		54.81 ± 2.26	28.62 ± 6.28
Fat[a]		0.74 ± 0.04	13.26 ± 2.76
Protein[a]		4.26 ± 0.26	6.28 ± 0.86
Ash[a]		1.09 ± 0.03	2.03 ± 0.09
Fiber[a]		0.83 ± 0.13	0.85 ± 0.15
CHO[a]		38.27 ± 1.96	48.96 ± 3.28
Energy content[b]	Kilojoule	5.78	14.20
	Calories	168.50	340.30

[a] All expressed in g/100 g of arepa.

[b] Expressed as energy units/100 g of arepa.

Alvarez (1981), Ecology of Food and Nutrition II, 203

Mottern, Buckle, and Pardo (1970) developed the following formula to enrich arepas: 88.7 percent opaque-2 corn flour, 5 percent soy flour, 5 percent corn gluten, and 1.3 percent salt. Opaque-2 corn is an experimental corn genetically developed with higher protein content (11.2 vs 9.8 percent) than that made from regular varieties as well as higher fat content (3.8 vs 1.2 percent). The enriched formula gave a calculated protein content of 15.3 percent and 0.62 percent lysine equivalent to 4.1 grams per 16 grams nitrogen. Comparison was made between enriched arepas with those made from precooked opaque-2 corn flour and not with those made from white corn flour. Panelists showed preference for arepas made from the unenriched opaque 2-corn over the enriched product. It was observed that incorporation of 10 percent soy or cottonseed flours changed the texture of the center of the arepa from slightly moist to gummy. At the 5 percent levels, this change was minimal. The addition of 10 percent corn gluten did not change the consistency noticeably, and even with the added corn gluten, the protein was still deficient in lysine (2.3 g per 16 g N) (Mottern et al., 1970).

Studies on nutritional value and enrichment of arepas are of great interest, but as reported by Alvarez (1981), they are relatively few. The lack of reported information on protein enrichment of arepas has created the need for such a study.

Single Cell Proteins

Single cell protein (SCP) is one of the few potential foods having no dependency on agricultural input or other harvesting operations. It can be a synthetic source of food whose composition is controllable. During the 1960's, there was an upsurge of development of SCP processes based on substrates from nonrenewable resources such as methane or petroleum from hydrocarbons and petrochemicals. These substrates were chosen for their low cost and availability in large quantities in certain geographic areas such as the Mediterranean region and Venezuela (Litchfield, 1977).

Phillips Petroleum Company and its subsidiary Provesta Corporation (Bartlesville, Oklahoma) are marketing a process to produce high quality protein (Wegner, 1983). The single-cell protein product generated through the process is called Provesteen. The process involves continuous fermentation using methanol or ethanol as a feedstock, which can be made from petroleum or natural gas. Phillips claim that for those countries without reserves of petroleum, biomass, forestry, and agricultural waste can be converted to the alcohol feedstock. Sugars such as glucose and molasses can also be used. In addition to the feedstock, the fermenter is supplied with ammonia and other nutrients, oxygen or air, and water. The fermenter is inoculated with the yeast culture at the onset (Figure 2). All the nutrient streams to the fermenter are filtered or heat-sterilized to prevent product contamination. The product stream from the fermenter is drawn off continuously and sent through a pasteurizer to a spray dryer. The Provesteen product is 60 percent protein, 5 percent lipid, and 18 percent carbohydrate and contains essential vitamins and minerals. Table II shows the Provesteen analysis including the amino acid profile (Provesteen, Phillips Petroleum Company Bulletin, 1984). The Phillips' process has the following advantages over other processes: simplicity of design, ultra-high cell density, maximum use of nutrients, elimination of waste streams, environmentally protective, modular plant construction, and a continuous fermentation process

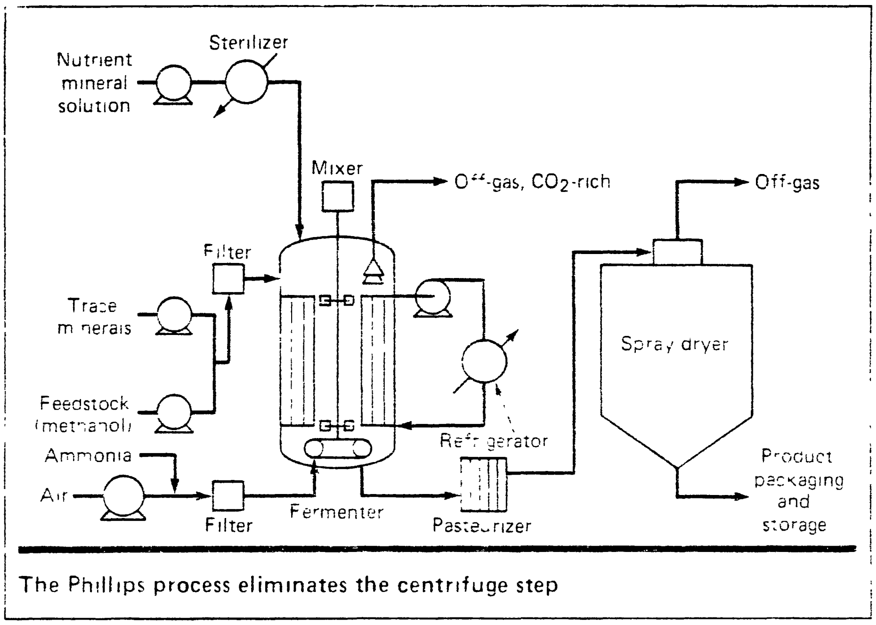


Figure 2. Phillips' Process (Provesteen)

(Wegner, 1983). According to John R. Norell, director of biotechnology at Phillips' Research and Development Department, a major advantage in the ultra-high cell density process is that all of the nutrients added initially or produced during fermentation are retained in the final product (Krieger, 1983). Moreover, centrifugation, an expensive process, is not required because the Phillips' process has cell densities of 120 to 150 grams of dry solids per liter in the creamy liquid stream coming from the fermenter. Conventional processes generally have cell densities of 30 to 40 grams of dry solids per liter. Feedstocks are fully utilized; there are no nitrogenous or organic effluents, avoiding environmental contamination. The final product "Provesteen" is a fine powder that can be used as is or extruded into pellets, granules,

TABLE II

PROVESTEEN ANALYSIS

Composition	**Weight(%)**
Protein	
Crude(% N X 6.25)	62.0
True(Biuret)	57.0
Ash	11.0
Moisture	4.0
Lipids	5.0
Carbohydrates	18.0

Mineral Content	**Weight(%)**
Calcium	0.09
Magnesium	0.30
Phosphorus	2.50
Potassium	2.50
Sodium	0.01
	PPM
Iron	340
Copper	36
Zinc	124
Manganese	26

Vitamin Content	**mg/kg**
Biotin	1.060
Folic acid	28.000
Niacin	640.000
Pantothenic acid	68.000
Vitamin B-6	56.000
Vitamin B-12	0.004
Thiamine	88.000
p-Aminobenzoic acid	73.000
Riboflavin	212.000
Choline	2500.000
Inositol	3420.000

Amino Acid Content	**Weight(%)**
Lysine	4.2
Arginine	3.5
Threonine	2.9
Glutamic acid	7.6
Glycine	2.8
Valine	3.3
Isoleucine	2.8
Tyrosine	2.0
Histidine	1.5
Aspartic acid	5.8
Serine	2.7
Proline	2.2
Alanine	3.4
Methionine	0.7
Leucine	4.4
Phenylalanine	2.2
Cystine	0.5
Tryptophan	0.6

Provesteen Bulletin (1984)

or flakes. Being a dry product, the shelf life is several years at ambient temperature. Provesteen has been proven safe with rats, pigs, chickens, ducks, fish, and ruminants, providing 50 to 75 percent of the protein required in the feed diet of those animals. Besides its use in animal feed, Provesteen may prove useful as a human food protein ingredient. Evaluation and nutritional studies of Provesteen have been conducted at Massachusetts Institute of Technology (MIT) since 1977. Scientific advances in this field are expected as a solution to reduce food shortages in many parts of the world, producing high quality protein at competitive costs.

SCP has been suggested for use as an extender in frankfurters or other fabricated foods, and as a protein enrichment for baked goods (Lipinsky and Litchfield, 1974). Yeasts seem to have acceptable functional properties in bread products. Zabik and Garrison (1975) added baker's yeast as a protein supplement in corn meal muffins. The trained taste panel scored the 10 percent supplementation muffins similar to the control for surface appearance, interior crumb color, texture, tenderness, moistness, and flavor attributes. The 20 and 30 percent supplementations received lower color and flavor scores than those of the control. The protein increased approximately one gram for each 10 percent addition of baker's yeast to the muffins. Zouranjian (1979) studied the effects of three different yeast single cell protein products from AMOCO Oil Company, Naperville, Illinois, on all purpose and whole wheat muffins at three different percentage levels (4 percent, 7 percent, and 9 percent). The taste panel ranked the muffins for appearance, mouthfeel, flavor, and overall acceptability. The results showed that one type of yeast flour, Toruway-49, was acceptable in muffins up to the

9 percent level, Torutein-LF was acceptable up to the 7 percent level, and Boost-100 was acceptable up to the 7 percent level. Protein levels increased significantly with the addition of the yeasts.

In baking experiments done by Lindbloom (1977), 10 and 12 percent yeast protein concentrate was substituted for the wheat flour. The protein content of the bread increased 20-40 percent compared to the unenriched bread. Food yeast (Torula) was used in the enrichment of corn and cassava meals in Brazil. Acceptability tests showed that no difference could be noted between the organoleptic characteristics of the enriched and unenriched recipes. Bressani et al. (1961) included 3 percent torula yeast in the formulation of INCAP Vegetable Mixture 9 and Mixture 14. The nutritive value of these mixtures has been confirmed by nitrogen-balance studies in children (Scrimshaw et al., 1961). Mixture 9 was produced on an industrial scale under the commercial name "Incaparina" (Bressani, Elias, and Scrimshaw, 1962). SCP concentrates, isolates, and textured products will have to meet the safety requirements of regulatory agencies in the United States and abroad. The Protein Advisory Group of the FAO presented guidelines on the safety of SCP products for human consumption, such as baker's yeast protein and protein products from yeasts such as <u>Candida utilis</u> (Torula). These guidelines have been accepted by many regulatory agencies (Litchfield, 1983; Zanetti, 1984).

Legumes

Pulses and legumes are very important foodstuffs in the diet of large populations in the tropics. From the list of foodstuffs available in developing countries as staples, legumes provide the highest amount of good protein, though deficient in the sulphur-containing amino acid methionine, while cereals supply the main source of calories, but are deficient in lysine. It is possible, therefore, to complement the protein of cereals with that of legumes (Bressani, 1973; Sgarbieri, Garruti, Morales, and Hartman, 1978). Several investigators have reported studies on wheat flour-legume flour blends for bread making. Legumes employed for such studies include soybeans (Pomeranz, Shogren, and Finney, 1969; Tsen and Hoover, 1973, and Tsen and Tang, 1971), chickpeas (Shehata and Fryer, 1970), peas (Jeffers, Rubenthaler, Finney, Anderson, and Bruinsma, 1978), fava beans (Lorenz, Dilsaver, and Wolt, 1979), navy beans (D'Appolonia, 1978); winged beans (Okezie and Dobo, 1980, and Cerny and Hutton, 1973). Supplementing corn with beans resulted in an increased protein intake because beans contain more protein (22.1 percent) than corn (9.5 percent). Bressani, Valiente, and Tejada, (1962) showed the optimum combination between the proteins of corn and those of black beans to be 72 grams of corn and 28 grams of bean, or a corn-to-bean ratio of 2.6 to 1. An increase in beans or in corn resulted in a decrease in protein quality to either side of the optimum combination point.

At higher levels of contribution by corn, lysine becomes limiting, while in the case of beans, methionine becomes the limiting amino acid. If corn and beans form the staple of a country, from the ratio of the intake of the two, one could predict which limited amino acid is the cause of malnutrition.

Similar results have been predicted for the other cereals. For sorghum, the maximum PER was obtained with a mixture of 70 grams of sorghum and 30 grams of beans (Ductra de Oliveira and Zappelinii, 1971). Rice had the highest PER when 80 percent of the protein content of the mixture was contributed by rice and 20 percent bean, which corresponds to 93 grams by weight of rice and seven grams of bean (Table III) (Elias, Bates, and Bressani, 1969).

Another interesting result was the mixture of maize and soybean. Maximum benefit was obtained when 40 percent of the protein was contributed by corn and 60 percent by soybean, which corresponds to 72 grams by weight of corn to 28 grams by weight of soybean (Elias et al., 1969), which is the same corn to bean ratio recommended by Bressani et al. in 1961. Sotelo and Hernandez (1980) determined the nutritional value of three different types of beans using chemical and biological methods. The highest nutritional value was found in the white beans followed by the ayocote beans; the black beans showed the lowest nutritional value. The phenylalanine and lysine contents in the three beans were superior to egg protein; however, the sulfur amino acid contents were very low.

Some studies have been conducted using navy beans. Yadav and Liener (1977) found an improved nutritional value by roasting navy beans. They showed that navy bean mixtures with cereal grains produced foods with high chemical scores which were little different from casein. Kakede and Evans (1965) described the nutritive value of navy beans (*Phaseolus vulgaris*). They found that unheated navy beans contain trypsin inhibitor and hemaglutinating activities which were destroyed by heating to 121°C for five minutes. They also reported that heat treatment increased the protein efficiency ratio of the navy beans.

Amaranths

Amaranths include approximately 60 species distributed in tropical, desert, and temperate regions of the world. Amaranths can be divided

TABLE III

PROTEIN VALUE OF OPTIMUM COMBINATIONS BETWEEN CEREALS AND LEGUMINOUS SEEDS

Distribution of protein in diet, %			
From cereal	From beans	PER	INCREASE %
100 rice	0 beans	2.25	10.4
80 rice	20 beans	2.62	
100 maize	0 beans	0.90	122.2
50 maize	50 beans	2.00	
100 wheat	0 beans	47	48.9
73 wheat	27 beans	70	
100 maize	0 soybean	1.50	90.0
40 maize	60 soybean	2.85	

Elias, Bates, and Bressani (1969). Arch. Latino amer. Nutr. 19:109

into four groups: grain types, vegetable types, ornamentals, and weeds (Cole, 1979). The commonly available species are hypochondriacus, cruentus, caudatus, edulis, and retroflexus. Most of these species are used as a grain in Central America, the greens as a vegetable in Africa, and the spikes as an ornamental in Europe (Cole, 1979). Amaranth is cultivated as a minor food crop in Central and South America. The grain amaranths have good potential as a food or feed crop because of their rapid growth pattern typical of the C4 photosynthetic pathway and their ability to resist moisture stress and to produce a good yield of grain in sorghum-like heads (Hauptli, 1977).

The greatest interest in amaranth is in Mexico. Nigeria and India are beginning to investigate the crop. In the United States, research, development, and promotion of the grain began in 1977 at the Rodale Research Center, but not so much for commercial interest as an attempt to help the developing world (Kauffman and Haas, 1983). Amaranth shows potential as a supplementary food for the Third World countries because of its protein content. Proximate analysis of several amaranth grain species indicate that protein, fat, fiber, and the ash minerals (especially sodium and calcium) are generally higher than in other common cereal grains. The mean protein content for all types is 16 percent, as compared to the following grains: corn, 9 percent; wheat, 10 percent; rice, 7 percent, and barley, 10 percent. The fiber content is 10.75 percent according to analysis conducted at Oklahoma State University.

The amino acid composition of three amaranth samples analyzed, edulis, cruentus, and hypochondriacus done by Becker, Wheeler, Lorenz, Stanford, Grosjean, Betsahart, and Saunder (1981) were similar; and each specie was relatively high in lysine and sulfur-containing amino acids (methionine and cysteine) commonly the limiting amino acids in cereal grains. The limiting essential amino acid in amaranths was found to be leucine followed by valine and threonine when compared with the FAO provisional amino acid scoring pattern (1973).

Becker et al. (1981) also found that starch was the most abundant carbohydrate component of amaranth at about 62 percent of the total weight of the grain. The amylose content of the A. hypochondriacus starch was 7.2 percent, considerably smaller than that of the wheat starch (22.2 percent), which greatly influences the physico-chemical properties of the starch. Adkins and Greenwood (1966) found that compared to wheat starch, the swelling power values of the starch from A. hypochondriacus were very low. Solubility values, however, were very high compared to wheat starch. Irving, Betschart, and Saunder (1981) reported that the very small size of starch granules were presumably responsible for the observed differences. Amylose content and starch granule's size have been reported to be factors which influence starch gelatinization (Greenwood, 1976). Since Amaranth starch has a lower amylose content and smaller granule size than wheat starch, those factors presumably account for a higher gelatinization temperature than that of the wheat starch (Lorenz, 1980). Water binding capacity values of the amaranth starch (127.3 percent) were higher than those of the wheat starch (71.8 percent). Table IV lists the nutritional composition of amaranth grain, and Table V lists the amino acid composition for amaranth flour. As mentioned previously, amaranth is shown to have relatively high levels of lysine, methionine, and cysteine. Sanchez-Marroquin, Maya, and Perez (1979) pointed out that the only factor restricting the use of the flour obtained from grinding the seeds is its low gluten content; something that must be considered when adding amaranth flour to baked products.

Amaranthus hypochondriacus flour was investigated using levels of 5, 10, 15 and 20 percent replacement for wheat flour by weight in bread systems. Sensory evaluation by a taste panel revealed an acceptable nutty flavor, but the texture was not silky, and crumb color was slightly darker as substitution levels of amaranth flour increased. Also, specific volume decreased as amaranth flour increased (Lorenz, 1980).

Morphological studies of Amaranthus cruentus using scanning electron and light microscopy have been carried out by Irving, Betschart, and Saunders (1981); and structure and composition of the seeds have been accurately described. Starch is present in the perisperm of the seed. Treatment with α- amylase caused partial digestion of the granules, and staining with iodine-potassium indicated which starch granules in the perisperm are composed of amylopectine (Irving et al., 1981). Betschart (1981) studied nutrient quality and content and its distribution inside the grain, determining milling conditions for separation of amaranthus seeds.

Amaranth is being investigated in order to improve the nutritional value of the diet. Amaranth flour is being incorporated into corn tortilla, a Mexican staple food, for enrichment of the product (Sanchez-Marroquin et al., 1979). Del Valle (1972) reported that a mixture of 80 percent corn and 20 percent amaranth flours resulted in a tortilla with acceptable flavor and no variation in cost in comparison to a standard tortilla. Lesieur (1983) studied the effects of amaranth flour on the sensory and objective qualities of Anadama bread, banana nut bread, bran rolls, and whole wheat English muffins. Substitutions of 10, 20, and 30

TABLE IV

NUTRITIONAL COMPOSITION OF AMARANTH GRAIN[a]
(100 grams)

Nutrient	Amount in 100 grams	RDA	% RDA in Amaranth
Protein	16.00 g	45.000 g	36.0
Fat	7.50 g	0.0	0.0
Carbohydrate (dff.)	62.00 g	0.0 g	0.0
Vitamins			
A	0.00	1.000 mg	0.0
B_1 (Thiamin)	0.14 mg	1.500 mg	9.0
B_2 (Riboflavin)	0.32 mg	1.800 mg	18.0
Niacin	1.00 mg	20.000 mg	5.0
B_6 (Pyridoxine)	0.00	2.000 mg	0.0
Pantothenic Acid	0.00	10.000 mg	0.0
Folacin	0.00	0.400 mg	0.0
B_{12}	0.00	0.003 mg	0.0
Biotin	0.00	NE	0.0
C	3.00 mg	45.000 mg	7.0
D	0.00	0.010 mg	0.0
E	0.00	15.000 mg	0.0
K	0.00	0.030 mg	0.0
Minerals			
CA	250.00 mg	800.000 mg	31.0
FE	15.00 mg	10.000 mg	150.0
MG	330.00 mg	350.000 mg	94.0
ZN	3.00 mg	15.000 mg	20.0
CU	0.70 mg	2.000 mg	23.0
NA	0.00	2500.000 mg	0.0
P	600.00 mg	800.000 mg	75.0
K	300.00 mg	2500.000 mg	12.0
Water	10.00 g		

[a] Senft (1980)

Note: To convert values to nutrient content per 100 calories, divide by 3.8 (100 g = kilocalories).

TABLE V

AMINO ACID ANALYSIS OF *AMARANTHUS HYPOCHONDRIACUS* (g/100 g protein)[a]

Amino Acid	Grams
Lysine	6.26
Histidine	2.74
Arginine	10.41
Tryptophan	1.89
Cysteic Acid	8.46
Aspartic Acid	8.46
Threonine	3.68
Serine	5.72
Glutamic Acid	16.52
Proline	4.46
Glysine	7.28
Alanine	3.99
Valine	4.46
Methionine	1.88
Isoleucine	3.92
Leucine	6.03
Tryosine	4.07
Phenylalanine	4.23

[a] Senft (1980)

percent amaranth flours for all purpose flours were done for all these bread systems. There were significant differences ($P<0.05$) due to amaranth replacement levels; however, for banana nut bread with 0, 10 and 20 percent amaranth substitution, the average mean scores for most attributes were high, indicating acceptability of the product. For the rest of the bread systems, sensory characteristics decreased as the level of amaranth flour substitution was increased. Panelists found dark color, strong flavor, and denser structured cells with amaranth substitutions. In nutritional analysis, amaranth flour increased values of the bread systems for protein, fiber, calcium, phosphorus, iron, and ascorbic acid.

There has been extensive work done on improving protein quality of basic foods that have limiting amino acids, and a variety of protein sources have been used. Although there have been some studies pertinent to the enrichment of arepas, more studies are needed to determine other legume flours and nonconventional high protein sources which could be acceptable in corn arepas. Nutritive content and acceptability studies of the protein-enriched products are also needed.

CHAPTER III

RESEARCH METHOD

The purpose of this research is to increase the amino acid content of corn arepas by substituting bean, amaranth, and yeast flours in five different formulas for corn flour, and then to determine the effects of these flours on the sensory and objective qualities of arepas. The research design, materials and equipment, preliminary study and product development, experimental procedures, data collection, and analysis of data are outlined in this chapter.

Research Design

Experimental research was conducted to test the hypotheses. In this type of research the experimenter determines conditions, manipulates the independent variables, and observes any alterations in the dependent variables (Best, 1981).

The independent variables in this research were the formulas. These formulas had amaranth flour, bean flour, and yeast powder substitutions, and there was a control formula of 100 percent corn flour with zero substitution. The dependent variables are the subjective and objective qualities of the five different products.

The experimental design used in this research is a split-split-plot, which is an incomplete block with whole blocks or plots subdivided into subplots or subunits (Steel and Torrie, 1980). The main-plot treatment represents the panelists, the split-plot treatment represents the use of red colored lights or regular lights, and the split-split-plot treatments represent the five different formulas of arepas. All treatments have been replicated three times.

The conditions which are maintained with regard to product preparation are product ingredients, preparation procedures, equipment, grilling and baking time, and storage procedures. In order to ensure that all arepas are cooked at a uniform temperature, free standing thermometers are placed to the front, back, center, and sides of the oven cooking surface. The heat in the various areas of the oven is the same with a range of 69°F. The oven thermostat setting of 350°F corresponds to a preheated internal oven temperature of 350°F as indicated by the free standing thermometers inside the oven. Arepas are placed in the oven when the oven temperature reads 350°F. Opening of the oven door and thermostatic controlled reheating caused fluctuation in the oven temperature during baking of ± 25°F. However, even with these fluctuations, all arepas in the oven at a given time were baking at the same temperature ± 3°F. The conditions which are maintained with regard to sensory evaluation include random assignment of the samples, testing area, lighting, time of day, seating, and privacy during sample evaluation.

Materials and Equipment

The white corn flour used in this study is a commercial flour manufactured in Venezuela by Productos Milpa C.A. under the trade name "Lucharepa." Venezuela exports this flour to Florida and other states where it is consumed by Latin American people. It differs from corn meal made in the United States in that the Venezuelan corn flour is milled from corn that has been precooked. Precooked flours do not develop viscosities as high as those of uncooked flours. This indicates that less moisture can be used in preparing the dough from precooked flours than from raw meal, permitting faster baking with less water to be driven off (Mottern et al., 1970).

The yeast used in this research is derived from Candida utilis (Torula); the trade name is "Provesteen." It is a fine, creamy colored powder. The product stream is pasteurized and dried. It was obtained from Provesta Corporation, Bartlesville, Oklahoma.

The amaranth flour used is the variety hypochondriacus, type R103, a grain type selected from the Rodale Organic Gardening and Farming Research Center world amaranth germ plasm collection which was developed by the New Crops Department at the Center (Penss Creek, Pennsylvania). Navy beans (Phaseolus vulgaris) were obtained from the local market in Stillwater, Oklahoma.

Major pieces of equipment used included an electronic top-loading digital balance (Mettler PC 4400, Delta Range), an analytical balance (Mettler H 35 AR, watts), an electric fry pan/griddle (Presto Model KC 17AT), an institutional electric griddle (General Electric, Model CR441), a conventional gas oven (Tappan, Model 36-3246), a food processor (Sunbeam, Model 14-21), an upright freezer (Hobart, Model H1), a Microwave Time-Saver (Tappan, Model 10/02016), an Instron Universal Testing Instrument (Model 1122), and a planimeter (Keuffel & Esser Company, Model 34232). The electric fry pan, institutional griddle, and gas oven were thermostatically controlled. A detailed description of materials and food research equipment are listed in Appendix A.

TABLE VI

RECIPE FOR AREPAS

Ingredient	Measure
Corn flour	100 grams
Salt	1 gram
Water	200 mls

1. Assemble ingredients and equipment.
2. Preheat oven to 350°F.
3. Mix all ingredients in a bowl and blend with a wooden spoon.
4. Stir with 10 strokes.
5. Let the dough stand five minutes.
6. Knead by hand until smooth (two minutes)
7. Form small patties approximately eight centimeters in diameter and two centimeters thick (a small dough ball is rolled and gently pressed to a flat shape).
8. Put the patties on a preheated (400°F) griddle for eight minutes (four minutes each side).
9. Bake in conventional oven at 350°F for 20 minutes.

Yield: three 100 gram arepas.

Preliminary Study and Product Development

During preliminary experimentation the first step was to convert ingredient measurements to metric equivalents and to standardize preparation procedures for arepas (Table VI). "Lucharepa" manufacturer's recommendations were followed for the proportions of 100 grams corn flour to 200 mls of water. The amount of salt was modified from 2.5 grams to one gram, the baking time was adjusted to 20 minutes at 350°F, and the griddle time was adjusted to eight minutes, four minutes each side, with the griddle set at 400°F.

The second step was to incorporate separately different levels of navy bean flour, amaranth flour, and yeast for corn flour, based on flavor, baking quality, appearance, and amino acid content. Several trials of arepas were conducted and it was found that suitable arepas could be made with a 10 percent substitution of amaranth flour for corn flour, a 10 percent substitution of yeast powder, or a 30 percent substitution of bean flour (Table VII). A change of color and flavor in the arepas was noted.

To make the navy bean flour, dried navy beans were finely ground with the Kitchen Aide mixer-food grinder attachment. Arepas with 10, 20, and 30 percent bean flour substitution for corn flour were made; these arepas had an acceptable color and texture, but a raw bean flavor was detected. When an equivalent amount of cooked bean paste was used in the same substitution levels, the arepas no longer had the objectionable raw flavor.

The procedure used to get the equivalent amount of dried bean flour using cooked bean paste was as follows:

TABLE VII

FORMULAS FOR AREPAS SHOWING
PERCENTAGE OF FLOURS USED

Formula 1	78% corn flour
	20% bean flour
	2% yeast powder
Formula 2	78% corn flour
	10% bean flour
	10% amaranth flour
	2% yeast powder
Formula 3	60% corn flour
	30% bean flour
	10% yeast powder
Formula 4	50% corn flour
	30% bean flour
	10% amaranth flour
	10% yeast powder
Formula 5	100% corn flour

1. Weigh 100 grams of navy beans.
2. Add 450 mls water, approximately.
3. Soak and cook until done (two hours and twenty minutes) and water is completely absorbed.
4. Weigh cooked beans (in this case the bean weight was 238 grams).
5. Divide weight of the cooked beans by 10 (238/10).
6. Put the entire weight of beans (238 grams) into food processor and blend until pureed.
7. Remove 23.8 grams of bean puree from food processor. This amount represents 10 grams or 10 percent of bean flour.
8. Subtract 10 grams, representing the dry weight of beans, from 23.8 to obtain added water:

$$23.8 - 10 = 13.8$$

From this procedure, it was established that 10 grams of uncooked beans was equivalent to 23.8 cooked beans (puree) and 13.8 mls water. This amount of water was then counted as part of the total water called for in the recipe. The correct amount of water was necessary to make an arepa that had a well hydrated flour and a dough that held its shape, but was not too moist. In the 100 percent corn flour arepa, each gram of flour required two mls of water to make a dough with the proper consistency. As seen in Table IX, however, the other flours did not require that much water, and amaranth flour appeared to require less water than bean flour. As the level of the various flours changed, the amount of water required to prepare a dough with the above characteristics also changed. The final water amounts were determined to be different for each formula (Table VIII).

TABLE VIII

INGREDIENTS FOR FORMULAS 1, 2, 3, 4, AND 5 OF AREPAS [a]

	Corn Flour (grams)	Bean Puree (grams)	Amaranth flour (grams)	Yeast (grams)	Salt (grams)	Tap water [e] (mls)
Formula 1	78	47.6[b]	--	2	1	130
Formula 2	78	23.8[c]	10	2	1	136
Formula 3	60	71.4[d]	--	10	1	100
Formula 4	50	71.4[d]	10	10	1	94
Formula 5	100	--	--	--	1	200

[a] Bean puree, amaranth flour, and yeast were substituted for corn flour by weight

[b] Equivalent to 20 grams bean and 27.6 mls water

[c] Equivalent to 10 grams bean and 13.8 mls water

[d] Equivalent to 30 grams bean and 41.4 mls water

[e] Does not include water added as a part of the bean puree

TABLE IX

WATER CONTENT OF AREPAS AS COMPARED TO CORN FLOUR IN 100 GRAMS (DRY WEIGHT) OF PRODUCT

Formula	Grams Corn Flour	Other Flours	Total Mls Water*
5	100	--	200
1	78	22	157
2	78	22**	149
3	60	40	140
4	50	50**	134

* Includes added water plus puree water

** Contains amaranth flour

From Table IX, it is shown that when the other flours were substituted for corn, the total amount of water required was less, and when one of the flours was amaranth, even less total water was required. This led to the conclusion that on a gram-to-mililiter basis, the corn flour absorbed more water than the other flours and the amaranth absorbed less water than the other flours.

The last step in the preliminary study consisted of combining different percentages of the substitution flours in order to develop a formula with an amino acid content comparable to the FAO pattern (Table VII).

The ingredients and procedures for the five formulas developed and modifications of water for each formula are seen in Table VIII. The procedure for making arepas was the same as in Table VI for all formulas except that it was necessary to cut in the bean puree with a pastry blender to obtain a better distribution and uniform mixing of the ingredients (see Step 3, Table VI).

The amino acid profile and protein content of corn flour and bean of the five arepa formulas were calculated based on Amino Acid Content of Foods and Biological Data on Proteins FAO: Nutritional Studies No. 24 (1970). For amaranth these were based on analyses provided by the Rodale Research Center, Pennsylvania (Senft, 1980), and for yeast on information provided by the producer, Provesta Corporation, a subsidiary of Phillips Petroleum Company, Bartlesville, Oklahoma. Amino Acid calculations for each arepa formula are included in Appendix D as well as a complete table as compared with the reference pattern of amino acid reported by the joint FAO/WHO ad hoc Expert Committee (1973). Calculations were reported as mg/g of protein.

Experimental Procedure

For each arepa formula six taste panel replications were done during one week, three under red colored lights and three under regular lights. In the preliminary study, it was determined that freezing and rethermalizing of arepas does not cause syneresis or appreciable texture or flavor changes; it was decided, therefore, to make all the arepas for different evaluation sessions at one time and freeze them. Weight of the ingredients in the formulas (Table VIII) were multiplied by 10 because the original recipe had a yield of three 100 gram arepas for Formula 5 and two and one-half 100 gram arepas for the rest of the formulas. In this manner a minimum yield of 25 arepas from each formula was obtained. Two days before sensory evaluation, a minimum of 110 arepas were made and distributed in five batches according to formula type. Each batch included 22 arepas. Batches of arepas were prepared following the procedure in Table VI.

Doughs were made by combining corn, bean, amaranth, or yeast flours with water after which the mixture was kneaded manually. Working of the dough is a very important part of the process since the arepas cannot be shaped without it, and deep cracks would be seen in the edges after baking. Arepas are traditionally shaped by hand, however, in industry, mechanical equipment is used in the shaping operation. Because of the absence of mechanical equipment, the following method was adopted to obtain uniform arepas and thus avoid bias among panelists. Pieces of dough weighing 100 grams $\pm$ 1 were pulled out, rolled into balls in moistened hands, flattened somewhat by pressure of the palms, then placed in a plastic pipe ring 7.7 cm in diameter by 1.8 cm in height. The piece of dough was pressed into the shape of the ring on a cookie sheet covered with wax paper by means of a wide spatula. A light coating of corn oil permitted repeated use of the ring without sticking. The arepas molded in that manner were ready for the two cooking procedures, grilling and baking. The thermostatically controlled griddle was set at 400°F, a high temperature, to get a fast gelatinization of the surface so that moisture would be retained and a soft crust formed (Mottern et al., 1970). Use of a lower temperature caused a drier surface and tougher crust. The second cooking of the dough was made in a regular gas oven.

While the first batch of arepas corresponding to Formula 1 were baking, the second batch was prepared. This procedure was repeated until the five batches were completed. Baked arepas were placed on wire racks and cooled for 45 minutes, then wrapped tightly with plastic film, placed in zip-lock storage bags, labeled and frozen.

Data Collection

Subjective and objective data were collected in this study. Subjective data were gathered from sensory evaluations. Objective data were obtained from tests for weight and volume, tenderness, moisture content, and estimation of protein and amino acid values.

Subjective Evaluation

Selection and Training of the Taste Panel. A six-member taste panel of Venezuelan students at OSU was selected after screening and training sessions. These sessions were accomplished according to recommendations of Amerine, Pangborn, and Roessler (1965) and Larmond (1977). Panelists were tested as to their ability to recognize the four basic tastes: sweet, salty, sour, and bitter. Weak solutions of sodium chloride, sucrose, quinine sulfate, and citric acid in solution with distilled water were used for the taste test (Appendix C). The panelists were also asked to rank sweetness among three different solutions of sucrose: 5, 10, and 15 percent (Appendix C).

An all corn arepa was tasted during the training session with the object of establishing criteria for a standard product. Other objectives of the training session were to instruct the panelists in the terminology used and in the use of the sensory evaluation form (Larmond, 1977). The panelists were informed that they comprised an essential research tool necessary to the objectives of the experiment. Written instructions and an agreed upon description of a standard arepa were printed and distributed to each panel member as well as posted in the taste panel booths (Appendix C).

Instrumentation. The instrument developed and used by the taste panel to measure subjective qualities of the five formulas of arepas was based on the modified magnitude estimation scale (Appendix C). This type of scale was used by Cathey (1981) to access the effects of collagen levels and freezing in beef, and by Matejek (1982) to access the effects of bran fiber in bread systems. The vertical lines for the scales were 5 cm in length. The attributes evaluated were appearance, crust color, interior color, crust texture, interior texture, overall mouthfeel, flavor, and overall acceptability. Space was provided on the sensory evaluation sheet for panelists to make comments regarding the sample product.

Sensory Evaluation Sessions. A total of six sensory evaluation sessions were held, beginning at 11:00 a.m., for three consecutive days. There were two sessions each day, one under red colored lights and the other under regular lights. Controlled conditions were maintained during the sensory evaluation period. The testing area was air-conditioned, without odor and noise. Panelists were provided with individual booths in a quiet room; natural lighting was excluded.

On the first day of the evaluation, six arepas from each batch were thawed at room temperature for two hours, then placed in a microwave oven (Tappan, Model 10/02016) with the defrost setting for three minutes. After this, six arepas from each batch were cut into halves with an Oster electric knife, and individual halves of each variation were placed in a random arrangement on coded white plates. The code numbers for arepas to be evaluated under red colored lights were different from those codes for the evaluations under regular lights. For each of the remaining sessions, five halves of arepas (one for each formula type) were arranged and codified on plates, rewarmed for one minute in the same microwave oven, and served to each panelist. Also, panelists were provided with distilled, deionized, ambient temperature water for mouth rinsing between samples.

To eliminate the possibility of systematic bias and minimize the effect of extraneous variables (Best, 1981), a system of random arrangement for sample presentation was developed utilizing the computer. For example, Table X shows the computer generated order on the plate that the various formulas were presented to the panelists for the first day under both lighting conditions. A different order was generated

TABLE X

ORDER OF PRESENTATION OF THE FORMULAS ON THE PLATE FOR ONE DAY UNDER EACH LIGHTING CONDITION

Day	Lighting	Panelist	Formula				
			A	B	C	D	E
1	Red	1	2	5	4	1	3
		2	3	5	4	1	2
		3	4	3	2	5	1
		4	1	3	4	5	2
		5	3	4	1	2	5
		6	5	2	1	3	4
	White	1	3	5	2	1	4
		2	3	4	5	2	1
		3	3	1	2	5	4
		4	4	1	3	2	5
		5	1	5	2	4	3
		6	1	3	2	5	4

A B C D E correspond to order of placement on the plate

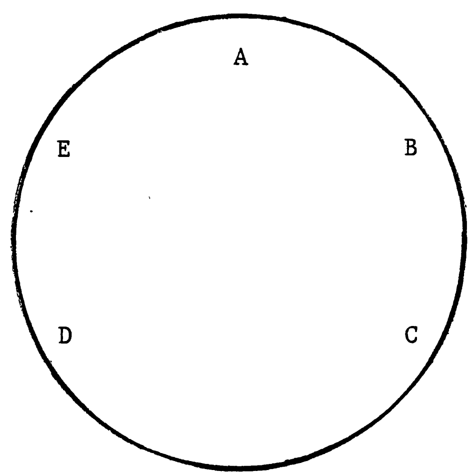


Diagram showing order of placement on plates for each test day (Table X). Also, the computer was used to generate random number codes for Formula 1 through 5 for each day and for each lighting condition (Table XI).

Objective Evaluation

One hour after each evaluation session for arepas, objective tests were prepared. Five arepas, one for each type, were randomly chosen. The data collected from three different days were averaged and analyzed statistically. The same conditions of thawing, microwave defrosting, and rewarming used for the arepas in the sensory evaluation was applied to the arepas used in the objective evaluation. The objective tests performed were weight and volume, tenderness, moisture content, and amino acid and protein content using Tables.

Weight and Volume. Arepas from each variation were weighed on a digital balance (Mettler PC4400, Delta Range) to the nearest 0.01 g, and volume was obtained by rapeseed displacement. The specific volume was then calculated from the weight and volume figures, dividing volume (cm^3) by the weight (g). The results are expressed as cm^3/grams (Campbell, 1979).

Tenderness. The Instron Universal Testing Instrument Model 1122 was used to measure tenderness of shear force (Kg/g). The crosshead of the Universal testing machine moves up or down at a constant rate of speed. For this study, the crosshead speed of the Universal testing machine was set to 100 mm/minute. As it moved, the force that was required to compress a sample of food was continuously recorded. The chart speed was set to 200 mm/minute and the scale load setting was 20.

TABLE XI

THREE-DIGIT CODES FOR FORMULAS 1-5
FOR EACH DAY AND FOR EACH
LIGHTING CONDITION

Day	Lighting	Formula				
		1	2	3	4	5
1	Red	746	859	772	932	364
	White	525	672	247	568	524
2	Red	352	066	040	054	367
	White	697	767	220	044	068
3	Red	072	266	883	875	553
	White	260	763	684	459	236

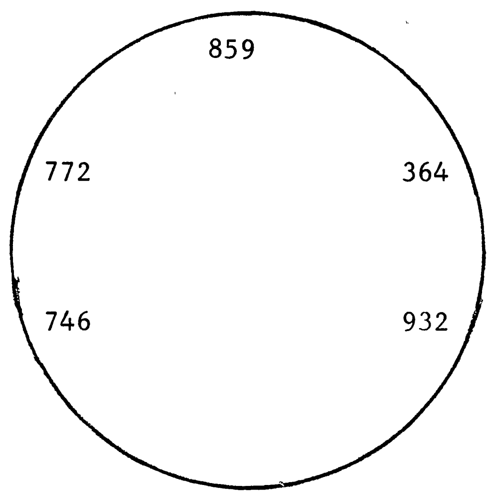


Diagram of how coded plate appeared for Panelist
No. 1 on first day under red colored light

A Kramer shear cell was used which consisted of a rectangular box with evenly spaced slits in the bottom. A series of ten blades moved through a sample of food in the box. As the blades moved, the arepa was compressed and extruded through the openings in the box (Campbell, 1979). A half arepa was used for tenderness determination. It was trimmed just enough to fit in the Kramer cell, and measured approximately 5.5 cm x 4.0 cm. Figure 3 shows the shape of the trimmed arepa.

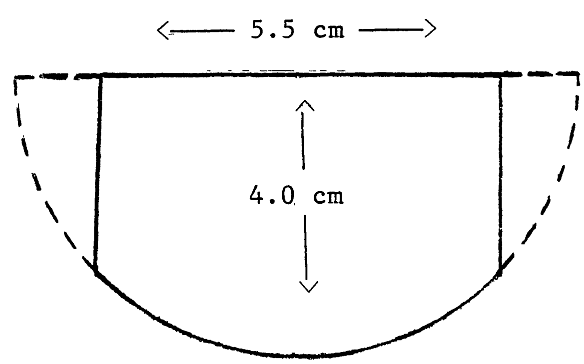


Figure 3. Shape of Trimmed Arepa

From the graph recorded by the Instom Instrument, it was possible to measure the peak force (Kg/g) required to shear the arepa as well as the area under the peak (in cm^2/g) which estimates internal tenderness. The area was measured using a plainimeter (Keuffel & Esser Company, Model 34232). The data from the three different days was collected and averaged for statistical analysis.

<u>Moisture Content</u>. Arepa samples were analyzed for moisture content according to the Association of Official Analytical Chemists' methods (1980). These were done each day that the sensory panel

convened. From the one-half arepa reserved for moisture analysis, a slice weighing approximately 10 grams was cut, finely ground by hand, and placed in preweighed and predried aluminum pans using a Mettler M35AR analytical balance. The vacuum oven temperature was 100°C; drying was to constant weight (approximately 48 hours). Moisture content was reported as percent of moisture using the following formula: percent of moisture = $\frac{\text{weight of wet sample - weight of dry sample}}{\text{wet weight sample}} \times 100$

Amino-Acid and Protein Content. Amino-acid profile and protein content in each mix were determined through the use of data from the Food and Agricultural Organization of the United Nations (FAO, 1970) from literature provided by Provesta Corporation (Shay, 1984), a subsidiary of Phillips Petroleum Company, Bartlesville, Oklahoma, and from the Rodale Research Center, Pennsylvania (Senft, 1980). Values were determined for tryptophan, leucine, lysine, methionine + cystine, isoleucine, phenylalanine + tyrosine, and valine and threonine, as shown in Tables XII-XVI.

Data Analysis

A split-split-plot design was used for this study. The Statistical Analysis System (SAS) was employed for data analyses (Barr and Goodnight, 1972). An analysis of variance (ANOVA) was performed on the taste panel scores, and the data on specific volume, shear force, area under the peak, and moisture content. After these data were calculated, the Duncan's Multiple Range Test (Steel and Torrie, 1980) was performed to determine the location of significant differences between pairs of mean values obtained from subjective and objective evaluations.

TABLE XII

AMINO ACID* AND PROTEIN CALCULATIONS
FOR FORMULA 1

Formula 1

78 grams corn flour (09.5% protein) ⟶ 7.41 grams protein
20 grams bean flour (22.1% protein) ⟶ 4.42 grams protein
2 grams yeast flour (62.0% protein) ⟶ 1.24 grams protein

13.07 grams protein in Formula 1

	TRP	LEU	LYS	MET + CYS	ISL	PHA + TYR	VAL	THR
78 grams corn	52.34	928.20	198.12	256.62	273.00	645.00	359.50	266.76
20 grams bean	44.60	337.00	318.60	84.40	185.40	342.60	203.20	175.60
2 grams yeast	12.00	88.00	84.00	24.00	56.00	84.00	66.00	58.00
	108.94	1,353.50	600.72	365.02	514.40	1,071.60	628.70	500.36
÷ 13.07								
Formula 1*	8.33	103.53	46.00	28.00	39.35	82.00	48.10	38.28
FAO Pattern*	10.00	70.00	55.00	35.00	40.00	60.00	50.00	40.80
Percent of FAO	83.30%	147.00%	83.00%	80.00%	98.40%	136.00%	96.20%	96.00%

* Mg/grams protein

TABLE XIII

AMINO ACID* AND PROTEIN CALCULATIONS
FOR FORMULA 2

Formula 2

78 grams corn flour	(09.5% protein)	⟶	7.41 grams protein
10 grams bean flour	(22.1% protein)	⟶	2.21 grams protein
10 grams amaranth flour	(16.0% protein)	⟶	1.60 grams protein
2 grams yeast	(62.0% protein)	⟶	1.24 grams protein
			12.46 grams protein in Formula 2

	TRP	LEU	LYS	MET + CYS	ISL	PHA + TRY	VAL	THR
78 grams corn	52.34	928.20	198.12	256.62	273.00	645.00	359.50	266.76
10 grams bean	22.30	168.50	159.00	42.20	92.70	171.30	101.50	87.80
10 grams amaranth	30.24	96.40	100.10	165.40	62.70	132.70	71.30	58.80
2 grams yeast	12.00	88.00	84.00	24.00	56.00	84.00	66.00	58.00
	116.88	1,281.10	541.22	488.22	484.4	1,033.0	598.3	471.36
÷ 12.46								
Formula 2*	9.37	102.81	43.44	39.18	38.87	82.91	48.02	37.82
FAO Pattern*	10.00	70.00	55.00	35.00	40.00	60.00	50.00	40.00
Percent of FAO	93.7%	145.00%	78.00%	111.00%	97.00%	138.00%	96.00%	94.00%

* Mg/grams protein

TABLE XIV

AMINO ACID* AND PROTEIN CALCULATIONS
FOR FORMULA 3

Formula 3

60 grams corn flour (09.5% protein) ⟶ 5.70 grams protein
30 grams bean flour (22.1% protein) ⟶ 6.63 grams protein
10 grams yeast flour (62.0% protein) ⟶ 6.20 grams protein

18,53 grams protein in Formula 3

	TRP	LEU	LYS	MET + CYS	ISL	PHA + TYR	VAL	THR
60 grams corn	40.18	713.64	152.36	197.39	210.00	496.18	276.56	205.20
30 grams bean	66.90	505.50	477.00	126.60	278.10	513.90	304.50	263.40
10 grams yeast	60.00	440.00	420.00	120.00	280.00	420.00	330.00	290.00
	167.08	1,659.14	1,049.36	443.99	768.10	1,430.08	911.06	758.60
÷ 18.53								
Formula 3*	9.02	89.50	56.63	23.86	41.44	77.17	49.18	40.93
FAO Pattern*	10.00	70.00	55.00	35.00	40.00	60.00	50.00	40.00
Percent of FAO	90.00%	127.00%	102.00%	68.00%	104.00%	128.00%	98.30%	102.00%

* Mg/grams protein

TABLE XV

AMINO ACID* AND PROTEIN CALCULATIONS
FOR FORMULA 4

Formula 4

50 grams corn flour	(09.5% protein)	⟶	4.75 grams protein
30 grams bean flour	(22.1% protein)	⟶	6.63 grams protein
10 grams amaranth flour	(16.0% protein)	⟶	1.60 grams protein
10 grams yeast flour	(62.0% protein)	⟶	6.20 grams protein
			19.18 grams protein in Formula 4

	TRP	LEU	LYS	MET + CYS	ISL	PHA + TYR	VAL	THR
50 grams corn	33.50	595.00	127.00	164.50	175.00	413.50	230.50	171.00
30 grams bean	66.90	505.50	477.00	126.60	278.10	513.90	304.50	263.40
10 grams amaranth	30.20	96.40	100.00	165.40	62.70	132.70	71.30	58.80
10 grams yeast	60.00	440.00	420.00	120.00	280.00	420.00	330.00	290.00
	190.60	1,636.90	1,124.00	576.50	795.80	1,480.10	936.30	783.20
÷ 19.18								
Formula 4*	10.00	85.34	58.65	30.00	41.48	77.17	48.84	40.81
FAO Pattern*	10.00	70.00	55.00	35.00	40.00	60.00	50.00	40.00
Percent of FAO	100.00%	122.00%	107.00%	86.00%	104.00%	129.00%	97.00%	102.00%

* Mg/grams protein

TABLE XVI

AMINO ACID* AND PROTEIN CALCULATIONS
FOR FORMULA 5

Formula 5

100 grams corn flour ⟶ 9.5 grams protein

	TRP	LEU	LYS	MET + CYS	ISL	PHA + TYR	VAL	THR
100 grams corn*	7.00	125.26	26.72	34.63	36.84	87.05	48.52	36.00
÷ 9.5								
FAO Pattern*	10.00	70.00	55.00	35.00	40.00	60.00	50.00	40.00
Percent of FAO	70.00%	179.00%	49.00%	99.00%	92.00%	145.00%	97.00%	90.00%

* Mg/grams protein

CHAPTER IV

RESULTS AND DISCUSSION

Bean, amaranth, and yeast flours were incorporated into five different formulations of arepas in order to increase and improve the amino acid content of corn arepas to a level comparable to the FAO pattern while maintaining acceptable organoleptic characteristics. Subjective qualities of the products were evaluated by a six-member panel. Objective tests included measures of specific volume, moisture content, and tenderness as evaluated by Instron determination of shear force (Kg/g) and measurement of the area under the peak (cm^2/g). Protein content and amino acid profiles were calculated using tables. The data thus developed were used to determine the differences in arepas when bean, amaranth, or yeast flours were substituted for part of the corn flour.

Subjective Evaluation

The instrument developed and used by the taste panel to measure subjective qualities of five formulations of arepas was based on the modified magnitude estimation scale (Appendix C) previously used by Cathey (1981) and Matejek (1982). The vertical lines for scales were five cm in length. After sensory evaluation by the panelists, their marks on the scales were measured with a ruler to the nearest 0.10 cm. Higher numbers indicated desirable ratings of the attributes. These data were statistically analyzed using the analysis of variance (ANOVA) procedure with the corresponding F tests. For attributes in which there were significant differences among the formulations, Duncan's Multiple Range Test (DMRT) was then used to show which attributes differed from others (Steel and Torrie, 1980).

Results of Magnitude Estimation Scaling

The mean score for each formula showed that sensory attributes of arepas decreased significantly as the level of corn flour decreased. The analysis of variance table with corresponding F tests is given for each sensory attribute in Table XVII. The results of Duncan's Multiple Range Tests for separation of means is shown in Table XVIII. The level of significance used to compare the mean scores was fixed at 0.05.

Upon examining the ANOVA tables (Table XVII) for sensory qualities of arepas for all five formulas, it was found that there were significant differences ($P<0.05$) among the average mean scores for all attributes due to flour substitutions in arepas. The attributes measured were appearance, crust color, interior color, crust texture, interior texture, overall mouthfeel, flavor, and overall acceptability due to flour substitutions in arepas. The F values for panelists, formula and interaction panelist-by-formula were all highly significant ($P<0.0001$).

The F values for lights and for the interactions panelist x light, light x formula, and panelist x light x formulas were statistically not significant ($P>0.05$); however, for the attribute crust color and crust texture the interaction panelist x light was marginally significant ($P<0.09$), which indicates that the panelists seemed to exhibit varying degrees of differences due to lights. There appeared to be no variation

TABLE XVII

ANALYSIS OF VARIANCE FOR SENSORY EVALUATION OF AREPAS

Attribute	Source	Df.	Sum of squares	F value	Observed probability
Appearance	Day	2	1.9710	1.04	0.3836
	Panelist	5	211.4498	44.65	0.0001
	Error (a)	10	9.4716		
	Light	1	0.0045	0.01	0.9277
	P x L	5	0.9711	0.37	0.8592
	Error (b)	12	6.2893	0.00	0.0000
	Formula	4	110.6108	67.16	0.0001
	L x F	4	1.6935	1.03	0.3968
	P x F	20	60.6637	7.37	0.0001
	P x L x F	20	6.0157	0.73	0.7856
	Error (c)	96	39.5280		
	Total	179	448.6695		
Crust color	Day	2	2.5387	1.09	0.3726
	Panelist	5	108.4364	18.65	0.0001
	Error (a)	10	11.6298		
	Light	1	0.7735	4.00	0.0687
	P x L	5	2.7584	2.85	0.0636
	Error (b)	12	2.3220		
	Formula	4	229.0903	102.32	0.0001
	L x F	4	2.8536	1.27	0.2854
	P x F	20	49.5663	4.43	0.0001

TABLE XVII (Continued)

	P x L x F	20	8.2376	0.74	0.7799
	Error (c)	96	53.7360		
	Total	179	471.9431		
Flavor	Day	2	0.4431	0.34	0.7203
	Panelist	5	129.6289	39.69	0.0001
	Error (a)	10	6.5328		
	Light	1	0.1560	0.69	0.4220
	P x L	5	2.5556	2.26	0.1143
	Error (b)	12	2.7093		
	Formula	4	249.7102	177.51	0.0001
	L x F	4	0.8675	0.62	0.6516
	P x F	20	47.7991	6.80	0.0001
	P x L x F	20	9.3257	1.33	0.1820
	Error (c)	96	33.7613		
	Total	179	483.4899		
Overall acceptability	Day	2	1.5601	0.98	0.4086
	Panelist	5	142.6436	35.85	0.0001
	Error (a)	10	7.9585		
	Light	1	0.0245	0.09	0.7711
	P x L	5	1.6285	1.18	0.3755
	Error (b)	12	3.3200		
	Formula	4	283.5733	254.31	0.0001
	L x F	4	0.4502	0.40	0.8055
	P x F	20	45.6500	8.19	0.0001
	P x L x F	20	4.4051	0.79	0.7192

TABLE XVII (Continued)

	Error (c)	96	26.7613		
	Total	179	517.9752		
Interior texture	Day	2	1.9847	0.51	0.6154
	Panelist	5	189.8564	19.51	0.0001
	Error (a)	10	19.4672		
	Light	1	0.0268	0.05	0.8339
	P x L	5	5.4364	1.86	0.1761
	Error (b)	12	7.0266		
	Formula	4	165.5141	92.41	0.0001
	L x F	4	0.8392	0.47	0.7587
	P x F	20	63.0485	7.04	0.0001
	P x L x F	20	7.5941	0.85	0.6507
	Error (c)	96	42.9880		
	Total	179	503.7824		
Overall mouthfeel	Day	2	3.4690	1.54	0.2618
	Panelist	5	151.9033	26.92	0.0001
	Error (a)	10	11.2856		
	Light	1	0.1868	0.22	0.6504
	P x L	5	4.4284	1.02	0.4463
	Error (b)	12	10.3826		
	Formula	4	229.4458	91.44	0.0001
	L x F	4	0.1092	0.04	0.9964
	P x F	20	60.8494	4.85	0.0001
	P x L x F	20	5.3887	0.43	0.9831

TABLE XVII (Continued)

	Error (c)	96	60.2226		
	Total	179	537.6720		
Interior color	Day	2	0.5097	0.24	0.7909
	Panelist	5	103.2309	19.45	0.0001
	Error (a)	10	10.6148		
	Light	1	0.0160	0.03	0.8560
	P x L	5	1.0736	0.46	0.7989
	Error (b)	12	5.6073		
	Formula	4	246.7992	149.65	0.0001
	L x F	4	1.1547	0.70	0.5937
	P x F	20	38.2654	4.64	0.0001
	P x L x F	20	4.5072	0.55	0.9381
	Error (c)	96	39.5813		
	Total	179	451.3606		
Crust texture	Day	2	4.8537	3.58	0.0672
	Panelist	5	106.3249	31.38	0.0001
	Error (a)	10	6.7768		
	Light	1	0.7093	1.50	0.2441
	P x L	5	6.1222	2.59	0.0821
	Error (b)	12	5.6733		
	Formula	4	279.4786	84.19	0.0001
	L x F	4	0.6631	0.20	0.9379
	P x F	20	50.7186	3.06	0.0001
	P x L x F	20	5.0102	0.30	0.9983
	Error (c)	96	79.6693		
	Total	179	546.0006		

TABLE XVIII

MEAN RANKS OF SENSORY EVALUATION (1,3) OF FIVE DIFFERENT FORMULAS OF AREPAS MEAN RANKS (2)

Formula	Appearance	Color		Texture	
		Crust color	Int. color	Crust texture	Int. texture
5	4.8250[a]	4.8556[a]	4.7778[a]	4.8972[a]	4.7417[a]
1	4.0778[b]	3.9889[b]	4.0528[b]	3.8833[b]	3.2500[b]
2	3.2556[c]	2.5861[c]	2.5861[c]	2.6667[c]	2.5306[c]
3	3.0000[c]	2.5472[c]	2.2194[d]	2.2222[d]	2.2778[cd]
4	2.6667[d]	1.7111[d]	1.6500[e]	1.3667[e]	2.1278[d]

Formula	Overall mouthfeel	Flavor	Overall acceptability
5	4.6583[a]	4.8944[a]	4.8528[a]
1	3.0417[b]	2.9083[b]	3.4056[b]
2	2.0444[c]	2.6222[c]	2.2722[c]
3	1.9722[c]	1.8389[d]	1.7111[d]
4	1.4833[d]	1.5389[e]	1.4389[e]

(1) = Mean ranks for six replications
(2) = Means for ranking values 1-5 where 5 is closest to the criteria for the standard product and 1 is farthest from the criteria

(3) = Values within column having no letter in common are significantly ($p<0.05$) different

in the panelists' evaluations due to the day of testing since F values among days showed no statistical differences (P>0.05).

The results of DMRT for separation of means (Table XVIII) showed that there were four groups due to formula type for appearance, crust, color, interior texture, and overall mouthfeel. The following order was observed for each of those attributes: the first group consisted of Formula 5, the standard product, which had the highest average mean scores. The second group was Formula 1 (78 percent corn, 30 percent bean, two percent yeast flours). The third group included Formula 2 (78 percent corn, 10 percent bean, 10 percent amaranth, and two percent yeast flours), and Formula 3 (60 percent corn, 30 percent bean, and 10 percent yeast flours). The fourth group, which had the lowest average mean scores, was Formula 4 (50 percent corn, 3 percent bean, 10 percent amaranth, and 10 percent yeast flours).

For interior color, crust texture, flavor, and overall acceptability average mean scores fell into five separate groups (Table XVIII). Formula 5, the standard product, was the highest rated for all these attributes, followed in order of decreasing ratings by Formula 1, Formula 2, Formula 3, and Formula 4.

The mean ranks of the five formulas for arepas showed that rankings for all attributes decreased significantly as the percent substitution of the other flours for corn flour increased. A consistent finding of the study was that Formula 5 (100 percent corn flour) received the highest mean scores, and the lowest mean scores were given to Formula 4, which was only 50 percent corn flour.

The mean scores for Formula 5, the standard, were significantly higher (P<0.05) than those of the rest of the formulas, but also, mean scores for Formula 1 were significantly higher ($P<0.05$) than those of Formula 2, 3, and 4. From these results, it was concluded that appearance, color (exterior and interior), texture (exterior and interior), mouthfeel, flavor, and acceptability attributes for Formula 1 were superior to the rest of the formulas with the exception of Formula 5, the standard product.

For Formula 5, 1, and 2 the means for all attributes measured are in the upper, desirable portion of the scale, or greater than 2.5, except overall mouthfeel and overall acceptability for Formula 2. For Formulas 3 and 4 the means for all attributes measured are in the lower portion of the scale, less than 2.5, except for appearance and crust color for Formula 3.

Comments of the Panelists

During the sensory evaluation period, a few of the panelists made the comment that Formula 3 and 4 had a too tender interior texture. Mottern et al (1970) reported corresponding results in the interior of arepas when they incorporated as much as 10 percent soy or cottonseed flours.

As the percentage of substitution flours increased, the color of arepas became darker than the standard product. Browning of the crust was only slightly increased, but in the interior browning was detected quickly by panelists in contrast to the standard arepa, which was very white. Two panelists detected a slightly bitter taste in Formulas 3 and 4, but it could not be determined whether the flavor was due to bean flour or the yeast or to an interaction of flavors.

Most of the panelists stated that Formula 1 was an acceptable product and that it was very close to the standard product. For Formula 2, panelists noted a slight difference in flavor from the product they were accustomed to, but they could not distinguish exactly what the flavor difference was. From the panelists' comments about Formulas 3 and 4, the distinct brown-gray color and the dense texture appeared to be the causes for low ranking.

Objective Evaluation

Objective evaluations were performed on product samples from each treatment the same day that sensory evaluations were made. These evaluations included determination of specific volume by rapeseed displacement, determination of tenderness by shear force (Kg/g) using the Instron Universal Testing Instrument and by measurement of the area under the peak (cm^2/g) using the planimeter and determination of moisture by drying.

Calculations of the protein and amino acid content of arepas were determined using FAO amino acid tables (1970), Senft (1980), and Shay (1984).

Specific Volume

Specific volume (cm^3/g) was calculated from the weight and volume figures. Although statistical analyses were not performed for weight and volume separately, the mean values for those qualities according to formula type are shown in Table XIX.

TABLE XIX

MEAN VALUES[a] FOR WEIGHT AND VOLUME

	F_5	F_1	F_2	F_4	F_3
Weight (grams)	69.67	77.48	78.71	79.48	80.19
Volume (cm^3)	108.30	110.00	106.60	103.30	106.60

[a] Mean values of three replications

The weight of the dough for each arepa before cooking was fixed to approximately 100 grams. From Table XIX it can be observed that weight decreased more for Formula 5 than the rest of the formulas. For Formula 5, a 30 percent baking loss in weight was observed, but for the rest of the formulas the baking weight loss was approximately 20 percent.

The results from the F test (Table XX) indicated that the means in specific volume among arepa formulas were significantly ($P<0.05$) different. When bean, amaranth or yeast flours were substituted for corn flour, the mean value of the specific volume decreased as the percentage of the flours above mentioned increased. These findings imply that the arepa became more compact as the level of corn flour decreased.

The DMRT (Table XXI) showed that there were significant differences ($P<0.05$) between formula 5 (100 percent corn flour) and the rest of the formulas (22 percent, 40 percent, and 50 percent corn flour substitution). The arepas were separated in two groups of average means for

TABLE XX

ANALYSIS OF VARIANCE FOR SPECIFIC VOLUME

Source	Df	Sum of squares	F value	Observed probability level
Day	2	0.0188	2.27	0.1651
Formula	4	0.1214	7.32	0.0088
Error	8	0.0331		
Total	14	0.1734		

TABLE XXI

DUNCAN'S MULTIPLE RANGE TEST FOR SPECIFIC VOLUME

Formula	Mean
5	1.5540^{a}
1	1.4194^{b}
2	1.3568^{b}
3	1.3304^{b}
4	1.3000^{b}

composed the first group. The second group was composed of Formulas 1, 2, 3, and 4. The F test (Table XX) did not show significant differences (P>0.05) among the days of the evaluation sessions.

Tenderness

The analysis of variance tables for shear force (Kg/g) and for area under the peak (cm^2/g) are presented in Tables XXII and XXIII respectively.

The shear force (Kg/g) and the area under the peak (cm^2/g) measurements used to evaluate tenderness were significantly different (P<0.05). As the percentage of corn flour decreased, both the force required to shear crust of the arepas and the areas under the peak, which measure interior tenderness, decreased. These objective findings agreed with the panelist's comments and evaluations, who ranked interior and exterior texture for Formula 3 and 4 as too tender (40 and 50 percent corn flour substitution respectively).

The results of the Duncan's Multiple Range Tests for tenderness by shear force and area under the peak (Tables XXIV and XXV respectively) showed two groups of means. For both tests, Formula 5 with the higher mean score composed the first group and Formulas 2, 3, and 4 with the lower mean score were the second group. Mean value for Formula 1 could be included either in group 1 or group 2. The information presented in the ANOVA tables (Tables XXII and XXIII) indicated that tenderness values for each formula of arepas did not differ significantly (P>0.05) between evaluation sessions.

TABLE XXII

ANALYSIS OF VARIANCE FOR TENDERNESS
BY SHEAR FORCE (Kg/g)

Source	Df	Sum of squares	F value	Observed probability level
Day	2	1.9348	0.94	0.4302
Formula	4	17.1478	4.16	0.0411
Error	8	8.2420		
Total	14	27.3247		

TABLE XXIII

ANALYSIS OF VARIANCE FOR TENDERNESS
BY AREA UNDER THE PEAK (cm^2/g)

Source	Df	Sum of squares	F value	Observed probability level
Day	2	0.0096	0.07	0.9289
Formula	4	1.6239	6.29	0.0137
Error	8	0.5166		
Total	14	2.1502		

TABLE XXIV

DUNCAN'S MULTIPLE RANGE TEST[2]
FOR TENDERNESS BY SHEAR
FORCE (Kg/g)

Formula	Mean[1]
5	4.1646[a]
1	2.9303[ab]
2	1.9394[b]
3	1.6101[b]
4	1.1788[b]

[1] Means from three observations

[2] Values within column having no letter in common are significantly ($p<0.05$) different

TABLE XXV

DUNCAN'S MULTIPLE RANGE TEST FOR
TENDERNESS BY AREA UNDER
THE PEAK (cm^2/g)

Formula	Mean
5	1.2107[a]
1	0.7488[ab]
2	0.4284[b]
3	0.4273[b]
4	0.3006[b]

Moisture Content

F tests (Table XXVI) for days of evaluation session and formula type showed no significant differences (P>0.05). The mean values for moisture were 54.40, 54.39, 52.30, 51.63, and 48.86 percent for Formulas 1, 2, 3, 5, and 4 respectively (Table XXVII).

Protein and Amino Acid Results

The substitution of bean flour, amaranth flour, and yeast flour by weight for corn flour in the arepa formulas studied increased the levels of protein and essential amino acids for all arepa formulas.

Formula 1. For Formula 1, total protein was increased 37.58 percent over that of the standard arepa. The essential amino acid increased with the substitution flours for Formula 1 were tryptophan, lysine, isoleucine, and threonine. Formula 1 presented the following relative amino acid values when compared to the FAO pattern: tryptophan 83.3 percent, leucine 147.0 percent, lysine 83 percent, methionine + cysteine 80.0 percent, isoleucine 98.4 percent, phenylalanine + tyrosine 145.0 percent, valine 96.2 percent, and threonine 96.0 percent (as shown in Table XII).

Comparing Formula 1 with the standard Formula 5, increases of 19.0 percent for tryptophan, 72.0 percent for lysine, 7.0 percent for isoleucine, and 6.0 percent for threonine were obtained.

Formula 2. The protein content for Formula 2 was 31.16 percent higher than the standard arepa. The essential amino acids increased for Formula 2 were tryptophan, lysine, methionine + cysteine, isoleucine, and threonine. Formula 2 presented the following relative amino acid

TABLE XXVI

ANALYSIS OF VARIANCE FOR
PERCENT MOISTURE

Source	Df	Sum of squares	F value	Observed probability level
Day	2	0.2106	0.01	0.9856
Formula	4	63.1919	2.18	0.1617
Error	8	57.9713		
Total	14	121.3757		

TABLE XXVII

MEAN VALUES* FOR PERCENT MOISTURE

Formula	Moisture Percent
1	54.40
2	54.39
3	52.30
5	51.63
4	48.86

* Means from three observations

values when compared to the FAO pattern: tryptophan 93.7 percent, leucine 145.0 percent, lysine 78.0 percent, methionine + cysteine 111.0 percent, isoleucine 97.0 percent, phenylalanine + tyrosine 138.0 percent, valine 96.0 percent, and threonine 94.0 percent (as shown in Table XIII).

Comparing Formula 2 with the standard Formula 5, increases of 25.0 percent for tryptophan, 63.0 percent for lysine, 12 percent for methionine + cysteine, 6.0 percent for isoleucine, and 5.0 percent for threonine were obtained.

Formula 3. The protein content for Formula 3 arepas was 95.0 percent higher than the standard Formula 5. The essential amino acid increased for Formula 3 were tryptophan, lysine, isoleucine, valine, and threonine. Formula 3 presented the following relative amino acid values when compared with the FAO pattern; tryptophan 90.0 percent, leucine 127.0 percent, lysine 102 percent, methionine + cysteine 68.0 percent, isoleucine 104.0 percent, phenylalanine + tyrosine 128 percent, valine 98.3 percent, and threonine 102.0 percent (as shown in Table XIV).

Comparing Formula 3 with the standard Formula 5, increases of 29.0 percent for tryptophan, 112.0 percent for lysine, 12.0 percent for isoleucine, 1.0 percent for valine, and 14.0 percent threonine were obtained.

Formula 4. For Formula 4, total protein was increased 102.0 percent over that of the standard arepa. The essential amino acids increased for Formula 4 were tryptophan, lysine, isoleucine, phenylalanine + tyrosine, and threonine. Formula 4 presented the following relative amino acid values when compared with the FAO pattern: tryptophan

100.0 percent, leucine 122.0 percent, lysine 107.0 percent, methionine + cysteine 86.0 percent, isoleucine 104.0 percent, phenylalanine + tyrosine 129.0 percent, valine 97.0 percent, and threonine 102.0 percent (as shown in Table XV).

Comparing Formula 4 with the standard Formula 5, increases of 43.0 percent for tryptophan, 119.0 percent for lysine, 13.0 percent for isoleucine, 29.0 percent for phenylalanine + tyrosine, and 13.0 percent for threonine were obtained.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this research was to increase the amino acid content of corn arepas by adding bean, amaranth, and yeast flours in five different formulas to the corn flour and to determine the effects of these additions on the sensory and objective qualities of arepas.

A review of literature revealed that supplementing conventional foods with little-known crops and unconventional proteins may give millions a better chance for adequate nutrition in the years ahead. Although many protein sources including soybean, single cell protein, fish protein concentrate, and other oilseeds have been incorporated into breads, tortillas, and other baked products, only one study using (soy bean) has been reported on protein enrichment of arepas. More studies are needed to determine what other high protein flours can be used and at what levels in arepas. Protein enriched arepas should also be tested for acceptability by taste panels and consumers.

The research was conducted using approved experimental procedures. A six member panel, all Venezuelans, evaluated the arepas using a score sheet developed specifically for arepas. The attributes rated by subjective evaluation were appearance, crust color, interior color, crust texture, interior texture, overall mouthfeel, flavor, and overall acceptability. The modified magnitude estimation scale with vertical lines five cm in length was used to evaluate the sensory attributes.

The Instron Universal Testing Instrument was used to measure tenderness, volume was measured by the rapeseed displacement method, and moisture content was determined according to AOAC methods (1980). The panelists underwent two training sessions, then rated each product three times under white lights and three times under red colored lights. The entire procedure required eight days. A split-split-plot experimental design was followed. Data were analyzed using Analysis of Variance, followed by Duncan Multiple Range Tests where differences were significant. Significance was determined at the P = 0.05 level.

Protein and amino acid values were determined through the use of data from the Food and Agricultural Organization (1970), Senft (1980), and Shay (1984). Amino acid values were determined for the amino acid tryptophan, leucine, lysine, methionine + cysteine, isoleucine, phenylalanine + tryosine, valine, and threonine.

SUMMARY

Hypothesis one (H_1) stated that there would be no significant difference among the five formulas (Table VII) associated with subjective qualities of arepas. Subjective qualities included appearance, crust color, interior color, crust texture, interior texture, mouthfeel, flavor, and overall acceptability. Hypothesis two (H_2) stated that there would be no significant differences among the five formulas (Table VII) associated with objective qualities of arepas. Objective qualities included tenderness, specific volume, moisture content, protein content, and amino acid profile. When subjective and objective characteristics for each variation of arepas were evaluated (Tables XVIII, XXI, and XXIV), both hypothesis were rejected.

Panel members detected differences in appearance, crust color, interior color, crust texture, interior texture, overall mouthfeel, flavor, and overall acceptability in all five formulas of arepas. Panelists could perceive a difference between standard arepas and those containing yeast, bean, or amaranth flours. The standard product, Formula 5, was the highest rated for all measured subjective attributes followed in order of decreasing ratings by Formula 1, Formula 2, Formula 3, and Formula 4. This order was always followed in the results of the study; and, for most attributes, each formula was significantly different from all others.

For Formulas 5, 1, and 2, all arepas scored at least 2.5 on a 5-point scale, with a 5 the optimum score, except that Formula 2 scored less than 2.5 for overall mouthfeel and overall acceptability. For Formulas 3 and 4, scores were lower than 2.5, except that appearance and crust color for Formula 3 were above 2.5 (Table XXVIII). Even under red lights panelists could distinguish interior and crust color differences, but these differences were not statistically significant. No significant differences among the evaluation session days were found.

The objective evaluation of specific volume (cm^3/g) indicated that yeast, bean, and amaranth flour substitution for corn flour significantly affected the specific volume of arepas, decreasing it as the level of corn flour decreased (Table VIII). Shear force (Kg/g) and the area under the peak (cm^2/g) values, as determined by Instron, decreased with the addition of yeast, bean, and amaranth flours. Formulas 1, 2, 3, and 4 were significantly more tender than the standard Formula 5 (Table XXIV). There were no differences in percent moisture due to yeast, bean, or amaranth (Table XXVII).

TABLE XXVIII

SUMMARY OF PROTEIN QUANTITY, PROTEIN QUALITY, AND ACCEPTABILITY OF THE FIVE FORMULAS FOR AREPAS

	Composition (grams)	Protein quantity		Protein quality*	
		Grams	% Increased	FAO Ref.	Overall acceptability **
Formula 1	78 g corn 20 g bean 2 g yeast	13.07	37.00	7.36	3.4056
Formula 2	78 g corn 10 g bean 10 g amaranth 2 g yeast	12.46	31.00	7.58	2.2722
Formula 3	60 g corn 30 g bean 10 g yeast	18.53	95.00	7.52	1.7111
Formula 4	50 g corn 30 g bean 10 g amaranth 10 g yeast	19.18	102.00	7.83	1.4389

TABLE XXVIII (Continued)

Formula 5 (Standard)	100 g corn	9.5	0.0	6.97	4.8528

* As determined by comparison of eight essential amino acids (EAA) with FAO reference pattern 8 = 100% or more of all eight EAA

** Means for ranking values 1-5, where 5 is closest to the criteria for the standard product and 1 is furthest from the criteria.

Results indicated that the protein and amino acid contents of all corn arepas were improved when bean, amaranth, or yeast flours were incorporated in the formulas when compared to the FAO amino acid pattern (Table XXX, Appendix D). Lysine and tryptophan, the most often limiting amino acid in corn, were improved in all formulas for arepas. Formula 4, in fact, was very similar to the FAO amino acid pattern and the protein content increased 103 percent over the standard arepa. This formula scored low (1.4), however, in acceptability on a 5-point scale, with 5 the optimum score. Formula 3 was also high in protein (95 percent increased), but was also rated low in acceptability (1.7). In Formula 2, the protein content increased 31 percent and the amino acid profile was improved for tryptophan, lysine, methionine + cysteine, and threonine; but the mean score for acceptability was low, 2.22.

In Formula 1, the protein content was increased 37 percent and the amino acid profile improved for tryptophan, lysine, isoleucine, and threonine as compared to the standard. For Formula 1, average mean scores were high in comparison to the rest of the substitution formulas, and the mean score for overall acceptability was 3.40. A summary of protein quantity, protein quality, and overall acceptability for each arepa formula is presented in Table XXVIII.

Conclusions

The incorporation of yeast, bean, or amaranth flours into arepas appears to be a feasible method of improving amino acid and protein contents of corn flour for arepas; but, when supplementation approaches the FAO pattern, acceptability decreases. Based on the results of this study, the protein content of Formula 1 (composed of 78 g of corn, 20 g of bean, and 2 g of yeast) was increased 37 percent over the standard. Also, the amino acid profile of Formula 1 was improved over the standard, but did not reach the level of the FAO pattern. In fact, for all formulas tested, the closer they approached the FAO pattern, the less acceptable they were. Formula 1, however, was judged acceptable (3.4 on a 5-point scale) even though it was served alone without butter or other foods.

If one consumed four Formula 1 arepas (150 g each) in a day, this could add approximately 26.14 g of protein and 1202 mg of lysine to the diet, thus making a substantial nutrient contribution. The supplementation flours could all be locally produced and are relatively inexpensive. The flours are also shelf stable and could be added to the arepa flour by the manufacturer. Formula 1 was rated as acceptable even when eaten alone; it showed definite improvement in both quantity and quality of protein, and a mix of this formula chould be made easily available locally. Therefore, arepas made from Formula 1 should be effective and economical in improving the nutrient intake of lower income groups of Venezuelans.

Recommendations

The following recommendations are given for further research:

1. Supplementation flours would be most successful in dishes such as casseroles, polentas, and desserts. Such foods which have a distinctive flavor, color, or texture and could serve to minimize any differences in the above attributes caused by the yeast, bean, or amaranth flour.

2. Yellow corn is used when white is not available. In the future

it should be used to mask the flavor and the brown-gray color given by yeast, bean, or amaranth flours.

3. Animal feeding experiments by growth determination would provide protein efficiency ratio (PER) values of the five formulas used for arepas.

4. Studies are needed regarding the nutritional quality of flours used for arepas, particularly as affected by processing.

5. Additional research is also needed to investigate the incorporation of other unconventional sources of protein into arepas in order to improve the protein and lysine deficiency of the corn-based diet eaten in many countries.

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APPENDIXES

APPENDIX A

MATERIALS

MATERIALS

Ingredients

Lucharepa corn flour

Amaranth flour

Provesteen yeast

Consumer's IGA TV navy beans

Mazola corn oil

Morton iodized salt

Utensils

Poly-vinyl chloride two-inch pipe for rings

Stainless steel (12 cup) bowls

Handi-Wrap plastic film

Ziploc storage bags (gallon size)

50-ml and 100-ml graduate cylinders

White plates

Equipment

Mettier M35AR analytical balance

Mettler PC4400 digital top loading balance

General Electric institutional griddle (Model CR441)

Tappan Range gas oven (Model 363246)

Sunbeam food processor (Model 14-21)

Hobart upright freezer (Model KC 17AT)

Mirro timer

Presto 12 inch fry pan-griddle (Model KC 17AT)

Tappan microwave (Model 10/02016)

Instron Universal Testing Instrument (Model 1122)

Keuffel & Esser planimeter (Model 34232)

APPENDIX B

DATA SHEET

DATA SHEET

Date____________________

Product________________________________

Griddle temperature____________________

Time in griddle________________________

Oven temperature_______________________

Time in oven___________________________

Time out of oven_______________________

	F_1	F_2	F_3	F_4	F_5
1. Code	____	____	____	____	____
2. Order of preparation	____	____	____	____	____
3. Placement in oven	____	____	____	____	____
4. Weight before cooking	____	____	____	____	____
5. Weight on day of sensory evaluation	____	____	____	____	____
6. Volume on day of sensory evaluation	____	____	____	____	____

APPENDIX C

SENSORY EVALUATION OF AREPAS

DESCRIPTION OF STANDARD AREPAS

Appearance: (exterior)

Moderately smooth surface, may have very shallow indentations visible around edges, but not surface cracks or deep indentations.

Color:

Crust - light golden brown
Interior - even, whitish

Texture:

Crust - slightly crunchy and chewy.
Interior - smooth, compact

Overall Mouthfeel:

Crunchy crust and moist interior.
Neither gummy, soggy nor dry.

Flavor:

Mild, pleasing, not strange flavor

Overall Acceptability:

Overall satisfaction in eating each product based upon the above description.

INSTRUCTIONS TO TASTE PANEL MEMBERS

At each session, you will be asked to evaluate ten formulations of arepas--five formulations under red lights and the other five under white lights. Please evaluate the visual characteristics before evaluating the eating characteristics. Samples should be evaluated in the order that the sample codes are listed (left to right) at the top of the scoresheet. After examining or tasting the samples, rank the sample on the vertical scale corresponding to the characteristic you are evaluating. A list of descriptions for standard arepas will be available at each booth in the sensory evaluation room. If you find any other difference between samples or have any comments which might be helpful in the evaluation of these products, please indicate them on the lines provided.

Distilled water will be provided for rinsing purposes. Please use it to rid your mouth of the flavor of one sample before evaluating the next sample.

Be sure to include your name, the date and code samples at the top of each sensory evaluation scoresheet.

For at least one-half hour before evaluation sessions, please try to avoid smoking, eating, drinking coffee or tea or chewing gum as these may alter your sense of taste.

Thank you for volunteering your time and effort for my research project.

BASIC TASTE IDENTIFICATION

NAME________________________ DATE____________________

Instructions: In front of you are four cups containing weak water solutions of chemicals representing the basic taste sensations. Your task is to identify the dominant taste in each cup.

Please rinse your mouth with water before you taste each sample. For each sample, please record on the ballot below if the sample has a sweet, salty, sour or bitter taste.

Sample Code	Taste Description

RANKING TEST

NAME________________________ DATE______________________________

Rank these samples for sweetness. The sweetest sample is ranked first, the second sweetest sample is ranked second and the least sweet sample is ranked third.

Please place the code number on the appropriate lines. Test the samples in the following order: 680 420 547

__________ __________ __________

1 2 3

INSTRUMENT

NAME__________________________

DATE____________________

CODE____________________

SENSORY EVALUATION OF VENEZUELAN AREPAS

APPEARANCE (exterior)
- moderately smooth surface
- cracked surface

CRUST COLOR
- light golden brown
- dark

INTERIOR COLOR
- even, whitish
- uneven, dark

CRUST TEXTURE
- slightly crunchy, chewy
- too hard too tender

INTERIOR TEXTURE
- smooth, compact
- coarse, light

OVERALL MOUTHFEEL
- chewy crust moist interior
- gummy, soggy or too dry

FLAVOR
- mild (not strange flavor)
- off-flavor

OVERALL ACCEPTABILITY
- acceptable
- not acceptable

COMMENTS: ____

APPENDIX D

AMINO ACID PROFILE ANALYSIS

TABLE XXIX

TABLE OF ESSENTIAL AMINO ACIDS

Essential amino acid	Corn (1) <u>Zea Mays</u>	Bean (2) <u>Phaseolus vulgaris</u>	Amaranth (3) <u>Amaranthus hypochondriacus</u>	Yeast (4) Provesteen
TRP	67	223	302.4	600
LEU	1190	1685	964.0	4400
LYS	254	1593	1001.0	4200
MET + CYS	329	422	1654.0	1200
ISL	350	927	627.0	2800
PHA + TYR	827	1713	1327.0	4200
VAL	461	1016	713.0	3300
THR	342	878	588.0	2900

Note: All values in the table are mg/100 grams of food, and were calculated from:

(1) FAO: Nutritional Studies, No. 24, 1970 (based on whole grain corn; may overestimate values actually present in arepa flour).

(2) FAO: Nutritional Studies, No. 24, 1970.

(3) Senft, 1980: Calculated from data given in terms of g/100 grams protein.

(4) Shay, 1984.

TABLE XXX

AMINO ACID PROFILE* OF THE FIVE FORMULAS
AS COMPARED TO FAO PATTERN**

Amino Acid	Formula 1	Formula 2	Formula 3	Formula 4	Formula 5 (standard)	FAO
TRP	8.33	9.37	9.02	10.00	7.00	10.00
LEU	103.53	102.81	89.50	85.34	125.26	70.00
LYS	46.00	43.44	56.63	58.65	26.72	55.00
MET + CYS	28.00	39.18	28.86	30.04	34.63	35.00
ISL	39.55	38.87	41.44	41.49	36.84	40.00
PHA + TYR	82.00	82.91	77.17	77.17	87.05	60.00
VAL	48.10	48.02	49.18	48.84	48.52	50.00
THR	38.28	37.82	40.93	40.81	36.00	40.00

* All values in the table are mg/g protein

** Food and Agriculture Organization of the United Nations. Energy and Protein Requirements. Report Series No. 52, Rome, 1973.

VITA 2

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