PERFORMANCE OF PROTEIN SUPPLEMENTED FLOURS IN CHAPATIS

by 4589

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TABLE OF CONTENTS

LIST OF TABLES v

INTRODUCTION 1

REVIEW OF LITERATURE 3

Protein Malnutrition in West Pakistan 3

Etiology 3

Incidence 5

Alleviation 7

Potential Sources of Protein for Human Consumption in West Pakistan 10

Fish 10

Cottonseed 11

Soybeans 13

Chapatis 15

Preparation 15

Type of Flour Used 15

Absorption 16

Mixing of the Dough 17

Resting of the Dough 17

Chapati Size, Cooking Time and Temperature 18

Quality Evaluation 19

Flavor Profile Analysis 21

History 21

Description 22

Amplitude 23

Character Notes 24

Aftertaste 25

THIS BOOK CONTAINS NUMEROUS PAGES WITH MULTIPLE PENCIL MARKS THROUGHOUT THE TEXT.

THIS IS THE BEST IMAGE AVAILABLE.

Panel Requirements and Procedure 25

Advantages and Disadvantages 26

PROCEDURE 27

Pilot Study 27

Materials 27

Chapati Preparation and Dough Evaluation . . . 28

Organoleptic Panel 30

Major Study 30

Materials 30

Chemical Analyses 31

Chapati Preparation and Dough Evaluation . . . 31

Organoleptic Panel 32

RESULTS OF THE PILOT STUDY 34

Controls 35

Organoleptic Properties of the Control Flour . 35

Use Properties of the Control Flour 35

Eating Qualities of the Control Chapatis . . . 35

Fish Protein Concentrate (FPC) Series 36

Organoleptic Properties of the Supplement and Flour Blends 36

Use Properties of the Flour Blends 36

Eating Qualities of the Supplemented Chapatis 37

Cottonseed Flour (CSF) Series 37

Organoleptic Properties of the Supplement and Flour Blends 37

Use Properties of the Flour Blends 38

Eating Qualities of the Supplemented Chapatis 38

RESULTS OF THE MAJOR STUDY 39
Controls 39
Organoleptic Properties of the Control Flour . 39
Use Properties of the Control Flour 39
Eating Qualities of the Control Chapatis . . . 40
Fish Protein Concentrate (FPC) Series 40
Organoleptic Properties of the Supplement and Flour Blends 40
Use Properties of the Flour Blends 41
Eating Qualities of the Supplemented Chapatis 41
Cottonseed Flour (CSF) Series 42
Organoleptic Properties of the Supplement and Flour Blends 42
Use Properties of the Flour Blends 43
Eating Qualities of the Supplemented Chapatis 43
Soy Protein Concentrate (SPC) Series 44
Organoleptic Properties of the Supplement and Flour Blends 44
Use Properties of the Flour Blends 45
Eating Qualities of the Supplemented Chapatis 45
DISCUSSION AND CONCLUSIONS 46
RECOMMENDATIONS 58
SUMMARY 60
ACKNOWLEDGMENTS 62
REFERENCES 63
APPENDIX 69

LIST OF TABLES

Page

Table

1. Sieve analyses of Gaines wheat flour used for chapati preparation 72

2. Proximate analyses of test flours and supplements 73

3. Amino acid analyses of Gaines wheat flour and supplements 74

4. Composite flavor profile of the control chapati . 75

5. Composite flavor profiles of FPC-supplemented chapatis 76

6. Composite flavor profiles of CSF-supplemented chapatis 77

7. Composite flavor profiles of SPC-supplemented chapatis 78

8. Characteristics introduced by chapati supplementation 79

9. Changes in the use properties of the control chapati flour introduced by increments in supplementation from 5-10-15% 81

10. Changes in the eating qualities of the control chapati introduced by increments in supplementation from 5-10-15% 83

11. Performance comparisons between each type of supplemented flour blend and the control 85

12. Flavor profile comparisons between each type of supplemented chapati and the control 86

13. Essential amino acid compositions of test flours and supplements 87

INTRODUCTION

Chapati, a type of wheat bread prepared from flour and water, is the principal staple food in West Pakistan. Among the poor classes chapatis may constitute as much as 90% of the total food intake (Chaudry, 1968). Such heavy dependence on a wheat-based foodstuff has resulted in a qualitative dietary protein deficiency, because wheat is an incomplete protein source (Howe et al., 1965). This condition has manifested itself in the wide-spread occurrence of protein deficiency diseases among infants and children, and in a state of generally poor health among many of the people of West Pakistan (Chaudry, 1968, Rahman, 1968 and West Regional Laboratories of PCSIR, Lahore, 1968).

Cereal supplementation with indigenous protein sources is one of the courses of action being pursued to alleviate dietary protein deficiency in developing countries. In 1968 an investigation of protein supplements for chapatis as consumed in West Pakistan was initiated by the Food and Feed Grain Institute at Kansas State University (KSU), as part of a larger project aimed at improving the nutritive value of cereal-based foods (contract no. AID/csd---1586). The purpose of the research is to develop a supplemented flour(s) for chapatis that will (1) be a substantial nutritional improvement over unsupplemented chapati flour and (2) be acceptable to West Pakistani consumers.

The investigation is being carried out in two phases--developmental and field testing. Several departments within the university are cooperating to develop processing techniques for the supplements and to assess the nutritive value of the protein sources and chapatis containing various amounts of the supplements. Since ultimately the consumer acceptability of the experimental flour(s) must be tested in West Pakistan, the supplemented flours and chapatis also are being evaluated organoleptically to select for field testing those products that have the greatest potential for consumer acceptance.

Flavor profile analysis is being employed by the organoleptic task group at KSU to evaluate the eating qualities of the supplemented chapatis. This method is a type of analytical sensory flavor testing that has been applied in the food industry for product development, improvement and screening (Caul, 1957). Other product attributes are observed by consumers; therefore, the dough handling and other use properties of the supplemented flours as well as the appearance of the supplemented flours and chapatis also are being assessed.

The baseline for evaluation is the control--the unsupplemented flour or chapatis. Since chapati is a product that has consumer acceptance, to avoid reversing its acceptability, any change in the product must not alter its characteristics (Matz, 1960). The "expert" panel (KSU research workers) thus is being used to determine whether changes resulting from supplementation can be detected. Once detectable differences have been determined, a laboratory consumer panel will be used to ascertain which differences the native consumer might be expected to notice, and the effect of the observed differences on product acceptability. The supplemented flours that appear to have the greatest potential for consumer acceptance then will be field-tested in West Pakistan.

The present study was designed to evaluate the performance of 9 protein-supplemented flours for chapati preparation. Three different levels each of fish protein concentrate (FPC), cotton-seed flour (CSF) and soy protein concentrate (SPC) were used to replace equal weights of Gaines 97% extraction wheat flour. The use properties of the flours were assessed, and both the flours and cooked chapatis were examined by a panel trained in flavor profile analysis.

REVIEW OF LITERATURE

Protein Malnutrition in West Pakistan

Etiology. Reportedly the nutritional situation in West Pakistan is like a two-edged sword, on one side of which there is a lack of enough food to eat and on the other the inadequacy of available foods with respect to nutrients, especially high quality protein (Chaudry, 1968). The per capita intake of calories for Pakistan has been estimated at 2080, 75% of which are said to be from cereals, with consumption of fruits, vegetables, meat and dairy products being very low (Food and Agriculture Division of the U. S. Agency for International Development, 1967).

According to Imtiaz (1962), the amount, composition and distribution of a nation's food supply are the basic determinants of the adequacy of the nutrition of its people. In West Pakistan the agricultural sector of the economy is largely subsistence oriented. Wheat is the country's most important foodgrain crop, occupying over one-fourth of all the land under cultivation (Ahmad, 1964). Until 1969, however, this dietary staple was not produced in sufficient quantities to meet the country's needs (Brown, 1970).

Livestock do not play a major food-providing role in West Pakistan (Foreign Area Studies Division of the American University, 1965). With increasing population density good pastureland has become scarce, as efficient land use has dictated that food crops be grown at the expense of animals' grazing (Ahmad, 1964).

Fish represent a potentially important source of food for West Pakistan, but one that is only beginning to be exploited (Gauhar, 1969). From 1959-1964 West Pakistan realized a 30% increase in fish production, and a 56% increase was predicted for 1964-1969 (Food and Agriculture Division of the U. S. Agency for International Development, 1967). The country's inland and marine waters are capable of even greater yields, but expansion of domestic markets is limited by as yet inadequate storage, processing and marketing facilities (Foreign Area Studies Division of the American University, 1965).

The availability of fruits and vegetables also is limited by physical facilities such as storage, refrigeration and canning (Foreign Area Studies Division of the American University, 1965). As a result, these foods are a luxury for the poor people (Imtiaz, 1962).

West Pakistan's food supply in itself reveals a situation conducive to the incidence of protein malnutrition among its people, but food consumption is affected by factors other than supply. Levels of income and education as well as religious beliefs influence the food choices people can and do make.

Wealthy persons constitute a minority of the population of West Pakistan, and the standard of living of the typical Pakistani villager differs little from that of his forebears. He thus is unable to purchase scarce and expensive food items such as meat (Foreign Area Studies Division of the American University, 1965).

Literacy, according to the census of 1961, was reported to encompass only 11.7% of the population of West Pakistan (Ahmad, 1964). Imtiaz (1962) noted that the mass of the people who are undereducated could not be expected to select a well-balanced diet even if the requisite food items were available.

Food taboos also are in existence in West Pakistan. About 97% of the population are Moslems, and of the remaining 3% some 662,000 are Hindus (Foreign Area Studies Division of the American University, 1965). The practice of Islam prohibits the consumption of pork, and Hindus rarely eat any meat at all.

Incidence. Food consumption patterns for the people of West Pakistan have indicated a conspicuous lack of high-biological-value protein in the diet, particularly among infants and preschool children and low-income families. Mahmood (1968) observed that the per capita intake of animal protein was extremely low in West Pakistan and stressed the need for certain essential amino acids--notably lysine, methionine and tryptophan--one or more of which generally are limiting in vegetable proteins.

A report issued by the West Regional Laboratories of PCSIR, Lahore (1968), also emphasized the lack of high-quality protein in West Pakistan. Protein deficiency was said to be prevalent among low-income groups and among infants and children as suggested by high mortality in the 1-4-year age group.

Rahman (1968) indicated that protein-calorie malnutrition affected about 85% of the children examined during the course of a food consumption survey conducted in Pakistan. Clinical manifestations included pot-belly, apathy, muscle wasting, marasmus and pre-kwashiorkor diseases. About 3% of these children were found to be suffering from severe protein malnutrition. Rahman (1968) cited the lack of protective foods, such as meat, fish and eggs, and the major role of cereals and other starchy foods in the weaning diet as causative.

Although many researchers have indicated that protein malnutrition in West Pakistan may be confined to specific groups, the preliminary results of the 1964-66 West Pakistan Nutrition Survey showed that a random sample of both rural and urban families were as a whole quantitatively sufficient but qualitatively deficient in dietary protein (Directorate of Nutrition Survey and Research, Government of Pakistan, 1966). Of the total protein intake, the percentages of animal protein consumed in rural and urban areas were only 11.4 and 16.8, respectively.

Assessment of the size of the protein gap in West Pakistan should not be based on the animal protein intake realized in the developed countries. Although Haq (1967) reported the daily animal protein consumption in Pakistan at only 16% of the total protein intake in comparison to 71% in America, the protein requirements of the people of a developing country differ from those of the more well-fed people of the world (Food and Agriculture Organization, 1962). In consideration of actual needs, the Food and Agriculture Organization (1963) set a short-term animal protein goal at 22% of the total protein for the developing nations. Comparison of the FAO figure with those derived for West Pakistan (11.4 and 16.8%) still reveals a sizeable protein gap.

In terms of future needs, the protein deficit appears even larger. At the present rate of food production and population growth in Pakistan, the increase in protein requirements in 1985 over those of 1968 has been estimated at 146% (West Regional Laboratories of PCSIR, Lahore, 1968). Even with low population estimates as a result of intensive family planning measures, necessary increases in the present supply of protein have been set at 118%.

Alleviation. Altschul (1968) stressed that protein malnutrition will not cure itself with time. Factors such as population growth and increasing ignorance and poverty will act synergistically with time to compound the situation unless something is done. Since it takes time to make available more animal protein, an intermediate solution to the problem must be sought.

Altschul suggested that a better quality diet should be made available at a cost low enough that even the poorest people could enjoy it.

The quality of the diet in West Pakistan reportedly cannot be improved by increasing the consumption of cereal grains because of the incomplete nature of cereal proteins. Wheat, for example, although it has a protein yield of about 12%, is deficient in several essential amino acids, lysine being the most limiting (Bressani et al., 1968, Howe et al., 1965, Osborne et al., 1914 and Rose et al., 1954). Furthermore, the biological value of wheat protein has been calculated at less than 60, and evidence indicates that if the biological value of any protein falls below 60, protein requirements cannot be met regardless of the quantity fed (National Research Council, Food and Nutrition Board, 1959). This statement is attested to by the fact that evidently West Pakistan already ranks among the highest foodgrain-consuming nations in the world, its average consumption of cereals--mainly wheat--exceeding recommended intake levels by nearly 23% (Hufbauer, 1968).

From the nutritional standpoint a vegetable protein diet can be improved either by adding the limiting or deficient amino acids or by properly combining different proteins to correct the amino acid deficiencies (Bressani et al., 1968). Supplementation of cereal flour with amino acids or protein concentrates has been suggested as one of the best immediate means of improving the quality of dietary protein in the developing countries (Altschul, 1970, Bressani et al., 1968, Bruins, 1964, Hand, 1966, Howe *et al.*, 1965, Parman, 1968 and Scrimshaw, 1969). This approach has the advantages of breadth and speed. A supplemented wheat flour could be incorporated into a wide variety of the traditional food products of West Pakistan, and readily find its way into the diets of all segments of the population without necessitating a change in food habits (Altschul, 1968, Bressani, 1965 and Snyder, 1967).

Some researchers have questioned the efficacy of amino acid fortification of cereal flour and the practicality of its application in the developing countries. Scrimshaw (1969) asserted that cereal grains, even when fortified with amino acids, do not contain a sufficient concentration of protein for young children. Hegsted (1968) agreed that amino acid fortification of flour might not be effective and added that, if it were, would be much too expensive. He remarked that although lysine is the most limiting amino acid in cereals, cereals alone rarely constitute the entire diet and there is no assurance that lysine will be the most limiting amino acid in the actual diets eaten. According to Chaudry (1968), supplementation with only lysine may be more harmful than beneficial. He reported that after 4 weeks, rats fed lysine-supplemented chapatis were depleted of their vitamin reserves and showed a depressed growth rate during the ensuing 4-week period.

The use of protein concentrates as cereal supplements in West Pakistan seems to be both feasible and advisable. Such concentrates would add protein as well as amino acids to wheat flour (Hegsted, 1968). Furthermore, untapped sources of both fish and vegetable protein are available in West Pakistan, and their utilization would not only hold down supplementation costs but also benefit the economy (Parman, 1968 and Parpia, 1968).

Potential Sources of Protein for Human Consumption in West Pakistan

Fish. Haq (1967) stated that fish represent a protein source that must be exploited in alleviating protein malnutrition in West Pakistan. He reported the per capita fish consumption in West Pakistan at only 5 pounds, which is low compared to estimates of 92 pounds for Japan and 12 pounds for the U. S. A. He added that although the Government has been successful in increasing fish production, consumption increases have been hindered by poor utilization practices together with a general dislike of fish among the people.

Parman (1968) noted that dietary inclusion of a protein concentrate prepared from fish provides an efficient way of using the large protein resources of the oceans for human feeding. In West Pakistan, FPC has been prepared from the by-products of the shark liver industry and from varieties of fishes previously considered to be inedible (Haq, 1967). Utilization of such low-cost raw materials has helped hold down production costs.

The nutritive quality of FPC depends upon the method of processing and the type of fish used in production. In general, it has been reported that FPC is well-suited to supply lysine to the diet and that methionine is the most limiting amino acid (Moorjani et al,,1970 and Yanez et al., 1967). Using 85% raw protein FPC prepared from elasmobranchi fishes, Haq (1967) found that wheat flour containing 2% FPC would satisfy the protein requirements of growing children and that wheat flour containing 3.5% FPC would be suitable for nursing mothers.

The stability, odor, flavor and color of FPC mainly are influenced by the processing methods used. Caiozzi et al. (1968) asserted that the presence of fat and amines in FPC has been responsible for the instability and unpleasant odor and taste that have adversely affected the acceptability of FPC-supplemented products. Numerous processes have been developed to produce a more acceptable FPC, however (Caiozzi et al., 1968, Haq, 1967, Knobl, 1967, Moorjani et al., 1970, Noyes, 1969, Roels, 1969 and Yanez et al., 1967). FPC now can be made that will keep for very long periods without the need for special storage conditions, and that is quite bland in aroma and flavor (Fish and Wildlife Service, Bureau of Commercial Fisheries, 1966, Knobl, 1967 and Parman, 1968). Parman (1968) commented, though, that the darkened color of FPC-supplemented products may still pose an acceptability problem.

Cottonseed. Oilseeds offer the largest single source of undeveloped protein in West Pakistan (West Regional Laboratories of PCSIR, Lahore, 1968), and cottonseed is Pakistan's major oilseed crop. During the 1966-67 season, 900,000 tons of cottonseed were primarily utilized for their oil content (Department of Marketing Intelligence and Agricultural Statistics, 1968). The seed cakes that remained after oil removal were fed to cattle or used as fertilizer. More recently, however, the use of this material for human feeding has been investigated (West Regional Laboratories of PCSIR, Lahore, 1968).

Cottonseed cake can be used to prepare a flour containing 50% or more protein (Parman, 1968). According to Noyes (1969), cottonseed cake is an excellent source of protein material, only slightly deficient in lysine and methionine. Bressani (1965) noted that the essential amino acid pattern of cottonseed protein compares favorably with the amino acid requirement for human adults, although it contains a relatively large amount of leucine, the effect of which on the nutritive value of the protein is not known. He also remarked that cottonseed protein contains relatively large amounts of nonessential amino acids, which contribute about 70% of the total nitrogen. The significance of this distribution of nitrogen is still not well studied, although animal proteins contain about 50% of their nitrogen as nonessential amino acids.

Kuppuswamy et al. (1949) were among the first to investigate the use of cottonseed flour as a supplement for low-protein-quality diets. Their results indicated that wheat flour supplemented with 10% cottonseed flour was capable of improving the quality of South Indian diets, supplying some of the deficient amino acids as well as additional protein. DeMaeyer et al. (1958) studied the nutritive value of cottonseed flour for children. They concluded that it was safe and had a relatively good nutritive value, which recommended it as a possible source of protein in the prevention of protein malnutrition. Cottonseed protein, in addition to being available, also is relatively low in cost. Since cotton is grown for its fiber, the oil and residual protein from its seeds are more economical than other oilseeds (Bressani, 1965).

Bressani (1965) commented on the taste and keeping quality of cottonseed protein and the color it imparts to food products when used as a wheat flour supplement. He indicated that it is bland or nutty in flavor and keeps quite well, except that moisture causes it to darken and decrease significantly in nutritive value. He cited its coloring effect as one of the disadvantages of using cottonseed protein as a flour supplement. It imparts a yellow-light-brown color to food products, and upon cooking this color darkens.

Noyes (1969) asserted that the biggest problem associated with the use of cottonseed as a food item is that it contains a polyphenolic pigment, gossypol, which is toxic to monogastric animals. Gastrock et al. (1969) indicated that gossypol also may combine with lysine rendering it unavailable nutritionally. Free gossypol can be removed, however, by properly processing and treating the cottonseed (Noyes, 1969 and West Regional Laboratories of PCSIR, Lahore, 1968), and gossypol-free cottonseed has been developed and introduced into West Pakistan (Khan et al., 1967).

Soybeans. Soybeans currently do not occupy a significant place in the agricultural economy of West Pakistan, but its use as a main crop has been recommended and is being investigated. Sattar (1966) urged that soybeans be grown as a source of oil for Pakistan. He noted that although approximately 95,000 tons of soybean oil are imported into the country each year, demand far exceeds supply. In an effort to meet this demand, research is being carried out in West Pakistan to determine the profitability of soybeans as an oilseed crop (Matlock, 1967).

If yields prove to be satisfactory, evidence indicates the usefulness of the seed cake as a food item. Properly defatted soybean flour contains approximately 50% protein. Concentrates of up to 70% and isolates of up to 90% protein can be prepared by removing soluble carbohydrates and minerals (Parman, 1968). Jones *et al.* (1944) found that the protein was of fairly good quality, being only slightly deficient in methionine and cystine. They also stated that soybean flour contains sufficient lysine to compensate for its deficiency in wheat flour. Shyamala *et al.* (1962) studied the protein value of chapatis supplemented with soybean flour, Based upon rat growth studies, they reported that chapatis supplemented with 10% defatted soybean flour had a protein efficiency ratio (PER) of 3.08, which was comparable to that of nonfat dry milk and was 51% greater than the PER for whole wheat chapatis.

Apparently the greatest obstacles to the general use of soybeans in food products are the bitter, beany flavor and objectionable odor and color of such products and their tendency to become rancid under ordinary storage conditions. Numerous processes have been developed, however, to improve the aroma, flavor, color and stability of soy products (Noyes, 1969).

Chapatis

Preparation. No standard method of chapati preparation exists in West Pakistan (Aziz *et al*., 1962). Chapati making is not primarily a commercial operation, and each housewife has received from her ancestors a slightly different concept of how to make a chapati. In general, chapatis are made of whole wheat flour from which the coarse bran has been sieved. This flour, known as atta, is mixed with water and sometimes salt and kneaded to form a dough of moderate consistency. The dough is rested and rolled into spheres. The dough balls are then flattened into circular shapes and baked and puffed on a "tawa" (heavy circular iron plate) or "tanoor" (mud-walled oven).

Type of Flour Used. Chapatis are prepared from whole wheat flour of approximately 95% extraction. Granulation may vary, though, since different types of stone mills as well as roller mills are used for atta preparation. Aziz *et al*. (1962) asserted that degree of fineness or coarseness is an important property of the atta for chapati making. They found that the finest atta was the best, as it had the highest water absorption.

Aziz *et al*. (1962) studied other quality considerations in wheat used for chapati flour. They reported that the wheat should be light in color, since a white or creamy color is desirable for chapatis. Because chapati dough is not fermented, they emphasized that the wheat gluten not be too strong. Finally, they stated that in view of the importance of chapatis as a dietary protein source, wheat for chapati preparation should have a protein content of at least 11%.

Chaudry (1968) examined the suitability of American-grown wheats for the making of chapatis. He observed that color was a major factor in reducing the acceptability of flours and chapatis made from red wheats. Over-all he found that Gaines soft white wheat was comparable to Pakistani wheats.

Absorption. The water absorption and other properties of flour vary with the variety of wheat used and the area in which it was grown (Matz, 1960). Aziz et al. (1962) reported that the absorption of atta prepared from Pakistani wheat varieties ranged from 70-76%. Qureshi (1959) observed that the absorption capacity of wheats grown in the State of Washington varied from 60-74%, and that in those cases where absorption was high, the dough had better handling properties and resulted in a chapati with better shape and texture. Chaudry (1968), using Gaines wheat grown in Washington state, incorporated 70-73% water in his chapati dough.

Murty et al. (1963) noted that the water absorption of atta for chapati dough may be influenced by mixing other types of flours with atta. Hedges (1968) found that supplementation of atta with wheat protein concentrate increased absorption, and according to Johnson (1970) CSF and SPC also may increase water requirements of the dough.

Matz (1960) commented on some of the functions of water in bakery products. He explained that water is needed for the hydration of protein and starch, thus facilitating gluten formation and starch swelling. The swelling of the starch helps bring dough ingredients into contact, and the gluten provides extensible material in which air may be entrapped during mixing. Air entrapment is important in steam-leavened products like chapatis, since water evaporates into the small air cells and then the air and water vapor expand on cooking.

Mixing of the Dough. According to Ahmad (1960), the purpose of mixing the dough is to aid in the hydration of the protein and starch and uniformly incorporate any other ingredients. Generally the mixing is accomplished by hand kneading the dough, although some researchers have used the more reproducible mechanical mixing methods for chapati preparation. Aziz et al. (1962) and Chaudry (1968) prepared their doughs in Hobart N-50 mixers using medium speed for 5 minutes.

Matz (1960) observed that the mixing requirements differ for different flours, and depend on the rate at which water in the dough combines with or hydrates the gluten. He explained that this rate may be influenced by differences in molecular structure and the way in which the protein particles are bound together in gluten strands. He added that mixing also may incorporate minute air bubbles into the dough which later can expand with steam vapor.

Resting of the Dough. Dough resting, like mixing, reportedly facilitates the hydration of starch and protein for optimum dough development (Aziz et al., 1962 and Knight, 1965). Additionally, it allows enzymatic breakdown of the starch-protein complex to occur (Aziz et al., 1962). Qureshi (1959) asserted that the duration of the optimal rest period is a specific varietal characteristic. For chapati dough, rest periods of from 25-60 minutes have been reported by various authors (Aziz et al., 1962, Hedges, 1968, Imtiaz, 1962, Murty et al., 1963, Rao et al., 1964 and Singh, 1949). Chaudry (1968),using Gaines wheat, found that 25-30 minutes was adequate.

Chapati Size, Cooking Time and Temperature. Considerable variation in the weight and diameter of chapatis and thus cooking time and temperature has been reported in the literature. Such variation is understandable in light of the fact that many different sizes of chapatis are consumed in West Pakistan. On-campus interviews with West Pakistani students have revealed that large, thick chapatis are eaten by farm workers in the fields, whereas wealthier persons generally eat small, thin chapatis, since bread is not such an important part of their diet.

Singh (1949) reported no dough ball weight or diameter and a chapati thickness of 1/8 inch. She heated a skillet until dry flour would brown within 20 seconds and cooked her chapatis for a total of 2 minutes and 50 seconds. Bains et al. (1952) and Murty et al. (1963) used 25-g dough balls, but the former group flattened out the dough as far as possible without breaking or tearing the chapatis, whereas the latter used a chapati diameter of 15 cm. Murty et al. (1963) initially cooked their chapatis on a hot pan, then puffed them for a few seconds on burning charcoal.

Aziz et al. (1962) used 100-g portions of dough, but did not indicate the chapati diameter. Shyamala et al. (1962) reported rolling small portions of the dough into thin disks about

5 inches in diameter and 1/8-1/4 inch thick and cooking them on a hot ungreased griddle for approximately 1 1/2 minutes on each side. Rao et al. (1966) cooked 45-g circles of dough, 7 inches in diameter, on a plate heated to 428-464° F for a total of 3 minutes each. Chaudry (1968) used a 50-g dough ball rolled to a 6-7-inch diameter, and cooked it on a gas-fired hot plate at 554-572° F for 2 minutes. Hedges (1968) reported using 30-g dough balls, each rolled to a 6-inch diameter. Using an aluminum griddle heated to 450° F over gas burners, she reported a total cooking time of 90 seconds.

Quality Evaluation. Evaluation of chapati quality has been complicated because of (1) difficulty in producing a reproducible test medium and (2) lack of a "standard" product. Ahmad (1960) asserted that 2 flours of the same chemical composition processed under similar conditions do not necessarily give chapatis of the same quality and character. He cited the importance to chapati quality of the amount of water used in dough preparation, but added that as yet no objective measurement exists to determine the correct amount of water for each flour. Although equipment is available to measure various properties of flours, these instruments were designed for the bread manufacturing industry and should be modified if used for testing flours for chapatis. As yet, only a person familiar with chapatis can determine the proper absorption by the feel of the dough.

In the absence of a "standard" chapati, quality evaluations have been based on certain chapati characteristics that are believed to be generally desirable. Ahmad (1960) stated that a chapati should be homogeneous in thickness, soft, smooth and easy to chew. It should not dry out rapidly, and should have a peripheral edge that has the same texture and consistency as the rest of the chapati. Murty _et al_. (1963) evaluated the quality characteristics of Indian wheats for chapati preparation in terms of the per cent water absorption of the flour, color and appearance of the dough and chapati puffing, appearance, texture and taste. They indicated that: (1) the absorption should be high, (2) chapati puffing should be rapid and full, (3) the crust should be uniform and creamy white, (4) texture should be soft, smooth and pliable, and (5) taste should be sweetish. Sinha (1964) noted that a desirable chapati should be: (1) creamy-yellow to white in color and neither red, brown nor yellow, (2) not leathery, tough, brittle or gritty, (3) not too dry, soft or sticky, even if eaten some hours after its preparation, (4) slightly caramel and sweetish, (5) well puffed on both sides, (6) well baked inside, and (7) speckled with a few dark spots.

Rating tests of some kind have been used by nearly all researchers who have attempted to measure chapati quality. Generally, several desirable chapati characteristics have been rated by an untrained taste panel composed of persons from Pakistan and/or India. Singh (1949) sought only an over-all acceptability rating for her chapatis. Her 7-member panel was composed of 4 Indians and 3 Americans. Each member assigned to each chapati a number from 1-10, 10 indicating the most acceptable product. In a composite score rating method used by Bains et al. (1952), the control chapati was assigned a maximum score as follows: appearance--20, palatability--35, texture--30 and chewing behavior--15. Chapati variations were then scored against the control by 6 Indian panelists.

Imtiaz (1962) used an 11-member panel of Pakistani and Indian students to rate chapati color, flavor, texture and acceptability. Each factor was assigned a score of from 1-4, 1 meaning poor and 4 very good. Chaudry's (1968) 7-member panel composed of students from India and Pakistan rated chapati color, flavor and texture, as well as the over-all acceptability of the product, using a scale of 1-10, 10 being the best score. Hedges (1968) developed her criteria from Chaudry's, but substituted appearance, moistness and tenderness for over-all acceptability. Three Indian students and 6 Americans served on her panel. They scored each chapati on a 7-point scale, 1 indicating a very undesirable product and 7 a very desirable one.

Flavor Profile Analysis

History. The flavor profile method was developed during the 1940's in the laboratories of Arthur D. Little, Inc. (ADL), when preference and difference testing were found to be inadequate for solving some of the problems encountered in flavor research. Sensory studies on the effect of monosodium glutamate, for example, revealed that no known method existed for expressing the phenomenon of the blending of flavor. Furthermore, the need was apparent for a more objective procedure for judging products, and one that would enable products to be examined separately as well as in groups (Cairncross et al., 1950).

Flavor profile analysis evolved from the natural process of describing or comparing food products on the basis of the nature and intensity of impressions perceived. The total sensory impression known as flavor includes the taste, odor and feeling factors of a food when it is taken into the mouth and prepared for swallowing (Sjostrom, 1967) as well as any effects perceived after swallowing.

In 1949 the flavor profile method was formalized and presented at the San Francisco meeting of the Institute of Food Technologists (Cairncross et al., 1950). Although the method was still in a formative stage at that time, it since has found wide acceptance. Caul (1957) commented that from the time of its origin, flavor profile analysis has been in constant use at ADL as well as in other laboratories in the U. S. and Europe. She reported that its application has permeated many industries other than food and beverage including chemical, pharmaceutical, packaging and cosmetics.

Description. The flavor profile generally includes an analysis of both aroma and flavor-by-mouth. Aroma analysis performs the dual functions of alerting the taste-tester to the aromatics he may expect to perceive in the flavor-by-mouth of a product, and yielding information about the odor that may not be deduced in any other way (Caul, 1957). Aroma and flavor findings of the taste panel each are reported in terms of overall impression or amplitude, and individual character notes according to their order of appearance and intensity.

Additionally the panelists record any in-the-mouth sensations perceived after swallowing.

Amplitude. The first part of the aroma or flavor analysis recorded is amplitude or over-all impression. It is the most difficult facet to understand and has been described in a number of ways. Caul (1957) referred to amplitude as breadth, and Cairncross et al. (1950) called it the sum of all intensities. Breadth is an apt term when interpreted to mean the general effect attributable to subordination of details, but the definition of amplitude as a summation of intensities is somewhat confusing since it cannot be derived by any mathematical procedure. This is partly because nonanalyzable components can contribute to the total flavor effect. Cairncross et al. (1950) further depicted amplitude as a measurement of aroma and flavor body. Body may be thought of as the nonanalyzable portion or supportive structure of aroma and flavor. For example, if the flavor notes of a product were to protrude from or be unsupported by the flavor complex, the body of the flavor would be small and the amplitude low (Caul et al., (1958).

The degrees used to express amplitude are based upon a scale similar to that used for intensity measurement of individual character notes and are as follows:

)(very low
1 low
2 medium
3 high.

The amplitude range is not fixed, however, but rather gauged to the particular product at hand. The profile panel must orient themselves for each type of product examined by establishing a new frame of reference (Amerine *et al.*, 1965).

Character Notes. Taste factors perceived usually are described as sweet, salty, sour or bitter, although they may be characterized further as, for example, chemical-sweet or sugar-sweet. Feeling factors such as astringency and coating may be defined with respect to the location of the effect (i.e., dry mouth, tongue coating, mouth coating). Other elements are described in associative terms such as cabbage-like or beany, or are directly related to a specific chemical or other reference material (Cairncross *et al.*, 1950).

Individual character notes are reported according to their order of appearance. This is made possible by standardized techniques of smelling and tasting, and may be more or less difficult depending upon the degree of blending of the aroma or flavor (Caul *et al.*, 1958). The order of appearance is important, since it is undesirable that an unpleasant note appear alone as either the first or the last element of a flavor complex (Caul, 1967).

Intensity is the degree to which each character note is perceived and is reported according to the following fixed scale:

0 not present
)(threshold or just recognizable
1 slight
2 moderate
3 strong.

The numerals actually are rather broad demarcations along a continuum composed of 29 just noticeable differences between 30 perceptual levels of intensity (Hainer *et al.*, 1954). Therefore, in order to designate narrower ranges, symbols such as + or - are used. The symbol 1+, for example, could indicate an intensity level between slight and moderate but closer to slight.

Aftertaste. The term aftertaste is somewhat of a misnomer, as it refers to not only taste but also any other flavor impressions discerned after a sample is swallowed. Usually they are few in number and normally are not assigned intensities unless it is particularly advantageous to do so (Caul, 1957).

Panel Requirements and Procedure. The profile method utilizes a panel generally composed of 4-6 experienced tasters. They are especially chosen, and thus do not represent the typical consumer (Dixon, 1970). Selection for panel membership requires that a person be intelligent, interested in flavor work and normal in his capacity to smell and taste. After selection, each panelist requires from 6-12 months of training (Caul, 1957).

The panel environment must be conducive to concentration. It should be well-lighted, quiet and virtually odor-free. Equipment used should be inodorous, and the panelists themselves should avoid contributing any distracting odors (Caul, 1967).

Orientation is the first phase of panel procedure. Informal sessions are conducted (1) to develop the best techniques for presenting and examining the product, (2) to develop descriptive terminology and (3) to define a frame of reference for expressing amplitude (Caul et al., 1958). After orientation, formal panel meetings begin. They consist of a closed panel followed by an open panel. During the closed session each panelist records his findings on a response sheet; during the open session findings are reported and discussed. At this time, since each panelist has a slightly different flavor background based upon his own experiences, differences in terminology are discussed. One of the panelists acting as moderator then summarizes the discussion and tabulates the data. The closed and open meetings are repeated until the entire panel is satisfied that the composite profile developed is truly representative of the characteristics of the product examined.

Advantages and Disadvantages. When Cairncross et al. (1950) first presented the flavor profile to the scientific community, they opined that it was the most versatile method available for use by small research panels, particularly as applied to flavor improvement studies. Caul (1957) noted other advantages of the flavor profile method. She reported that it provides a written record of a flavor that can be used for future reference, that it shows likenesses as well as differences between and among products and that it yields reproducible and reliable results.

One of the disadvantages of flavor profile analysis is that results cannot be analyzed statistically. The numerals used to report amplitude and intensity are only symbols and should not be treated quantitatively (Amerine et al., 1965). Other disadvantages include the training requirement for panelists, the experience and knowledge required to interpret flavor profiles (Caul, 1957) and the bias that may be introduced during the open panel session (Krum, 1955).

The introduction of bias requires some explanation since it is open to dispute. Soloman E. Ash and other psychologists have shown that the hazard of bias exists in round-table procedures because the opinions of individual members of the group may influence over-all group opinion (Hall, 1958). In practice, Hall found that the group judgments of an experienced panel were influenced by abnormal observations expressed by one person, the results being significant at P = 0.01. He described a modified flavor profile method that eliminated the open panel following each closed session and, in his opinion, retained most or all of the virtues of the profile method. The modification involved the use of the round-table primarily during panel orientation and subsequently only as unfamiliar character notes appeared during examinations. Round-table discussion according to Caul *et al.* (1958) is an asset rather than a liability of the flavor profile method. They asserted that regular use of discussion actually increases the worth of each panelist as a flavorist, since it gives all members the opportunity to benefit from the knowledge and experience of others and increase their interpretive abilities.

PROCEDURE

Pilot Study

Materials. Seven test flours were received from the Department of Grain Science and Industry at Kansas State University in July of 1969 and stored at 34-40° F in deodorized glass jars in the Department of Foods and Nutrition. Gaines, a soft white wheat grown in the Pacific Northwest (C. I. No. 13448), was used to prepare the 95.8% extraction control or unsupplemented flour.

On May 2, 1969, the wheat, which had been treated according to standard cleaning house procedures, was ground in a Brabender Rapid Test Experimental Mill and sifted on a Forsburg 18 wire sifter. The sieve analysis of the control flour appears in Table 1 of the Appendix. Five-pound batches of 6 supplemented flours were subsequently prepared by replacing the Gaines flour (by weight) with 5, 10 and 15% each of fish protein concentrate (FPC) and cottonseed flour (CSF) and blending each batch for 15 minutes in a Wenger Ribbon Mixer.

The supplements initially were delivered to the Department of Grain Science and Industry where they were held in cold storage (40° F). The FPC (Food Grade Type I Marine Protein Concentrate) was obtained from Alpine Marine Protein Industries, Inc. (AMPI), in November of 1968. It was certified to have been produced in accordance with regulations established by the U. S. Food and Drug Administration (Roels, 1969) and made by AMPI's patented ethylene dichloride azeotropic extraction process, using only hake and hake-like fishes. According to specifications, its aroma and flavor were described as faint, and traces of ethylene dichloride and isopropyl alcohol were reported to be present. In January of 1969, glandless CSF was obtained from Texas A & M University, where it had been batch processed in a pilot research lab and stored for 8 months. The meal had been mildly cooked and flaked in a steam jacketed cooker at 180° F for about 10 minutes.

Chapati Preparation and Dough Evaluation. A standardized procedure was developed to provide a reproducible test medium.

The method was used for the preparation of all chapatis (supplemented as well as controls) so that differences among chapatis could be attributed to differences in flour composition alone. Dough evaluation was based on appearance, aroma, mixing, handling and cooking properties.

The dough was prepared from 300 g of flour and 207 ml demineralized distilled water and mixed on a Hobart Model N-50 mechanical mixer for 1 minute at low speed and 3 minutes at medium speed. After mixing, the dough was placed in a Pyrex® casserole, sprinkled with 5 ml demineralized distilled water, covered with a lid and left to rest at room temperature (76-78° F) for 30 minutes.

After resting, each batch of dough was divided into 10, 50-g pieces and hand-shaped into spheres. Each sphere was flattened with a rolling pin into a disk 6 1/2 inches in diameter, as marked on the rolling surface. Approximately 1 g of flour was used for rolling to prevent the chapati from sticking. More than 1 g of flour was used when the dough was overly sticky.

The rolled chapati was transferred quickly onto a cast iron griddle preheated to 450° F over 2 automatically controlled gas burners. The temperature was monitored with a calibrated grill thermometer. After 45 seconds the chapati was turned over and pressed with a soft cloth to spread the steam uniformly within the chapati and create 2 layers. In 45 seconds it was turned for the second time and removed from the heat 10 seconds later, making the total cooking time 1 minute and 40 seconds. After being removed from the heat, the chapati was placed on a preheated china plate, covered with a cloth and immediately delivered to the organoleptic panel room.

Organoleptic Panel. The raw flours and chapatis were examined by the author and her instructor in flavor analysis during the period between July 23 and September 25, 1969. Analyses were conducted in a laboratory which was quiet, low in odor level and illuminated by daylight. After orientative examination of the flours was concluded, the chapatis were screened to eliminate those that were obviously different from the control. Differences were determined on the basis of aroma, flavor, texture and appearance of the chapati. The remaining samples were served and examined according to a "standard" procedure. Each cooked chapati was torn into halves and each half placed on a preheated china plate and served to a panelist. As soon as the samples were sufficiently cool, both outside surfaces and the inside were examined for aroma and flavor by the flavor profile method. Appearance and texture also were noted. A discussion period followed each session, and examinations proceeded until it was agreed that all samples had been characterized adequately and a word description developed for each chapati variation.

Major Study

Materials. The materials were the same as those used in the pilot study and were prepared and handled in the same way except that (1) the Gaines flour used for the control and in all blends was a 97.0% extraction flour milled in 3 batches on December 4, 1969, and (2) soy protein concentrate (SPC) was also used as a supplement at the 5, 10 and 15% replacement levels. The sieve analyses of the 3 batches of Gaines flour appear in Table 1 of the Appendix. After the sieve analyses were made, the batches were combined to yield a single control flour. The Swift Chemical Company supplied the SPC (Fine Grind Swift's Food Protein) in May, 1969. Specifications described it as a light-tan-colored, bland soybean-derived food ingredient initially screened through a U. S. Standard Screen size No. 40.

Chemical Analyses. The test flours and the supplements were analyzed for nitrogen, moisture and ash content (Table 2, Appendix) according to AOAC methods 2.044, 13.004 and 13.006, respectively (Association of Official Agricultural Chemists, 1965). The amino acid compositions of the control flour and the supplements (FPC, CSF and SPC) were determined by column chromatography with a Beckman® Model 120C Amino Acid Analyzer (Table 3, Appendix). All analyses were conducted by the Department of Grain Science and Industry.

Chapati Preparation and Dough Evaluation. A graduate student from India who was familiar with chapatis assisted with the preparation and evaluation of the doughs. As in the pilot study, a standardized procedure was used for the preparation of all chapatis, and the characteristics evaluated were the same as in the pilot study. The method of preparation was slightly different, however, because a different control flour was used. The absorption was 69% rather than 70.6% (i. e., the dough was prepared initially from 202 instead of 207 ml of demineralized distilled water); the resting period was extended from 30 minutes to 1 hour; and after the resting period the dough was mixed at medium speed for an additional 1 minute, then rested again for 15 minutes. Flour used during rolling was limited to 1 g. The chapatis were cooked for a total of 1 1/2 minutes--30 seconds each on sides 1 and 2 and subsequently another 30 seconds on side 1--and then were placed in the cloth-lined drawer of a portable warming tray and kept there until delivered to the organoleptic panel room.

In practice, 2 adjustments had to be made in the preparation procedure. First, the griddle temperature sometimes reached 500° F during cooking; thus cooking times were decreased as much as 25 seconds in an attempt to give each chapati approximately the same heat treatment. Secondly, the amount of water in the basic recipe was insufficient to prepare a dough from the atta supplemented with SPC at the 10 and 15% levels. Consequently, additional water was added at the rate of 1 ml/g of SPC (Johnson, 1970), bringing the total amounts of water added during dough preparation to 232 ml (202 + 30) and 247 ml (202 + 45) for the 10 and 15% SPC supplemented doughs, respectively.

Organoleptic Panel. The chapatis were examined by a 6-member panel trained in flavor profile analysis during 2 semesters of course work at KSU. Their experience with the flavor profile method included 10 days of orientative work with chapatis. Participants included 4 graduate students at KSU, the author and her instructor in flavor analysis. The author served as panel leader.

Panel sessions were 30-60 minutes in length and convened 5 days weekly for a period of 4 weeks (December 8-19, 1969 and January 5-16, 1970). The testing period was limited in time by the availability of the panelists. The panel schedule appears in Form 1 of the Appendix. All meetings were held in a room that was quiet, virtually odor-free and well-lighted (incandescent).

The 10 test flours and the 3 supplements were examined by the panel for orientation. All 10 variations of chapatis were examined at least twice. The controls were examined more often to re-orient the panel to the baseline. No more than 2 kinds of chapatis and/or 5 flours were presented to the panelists in any one session, and the order of examination was such that each chapati variation was the first to be presented in at least 1 session. During the first week of testing, samples were identified for the panelists prior to tasting, but subsequently the identity of the samples was not revealed.

Chapatis samples were served and examined according to a "standard" procedure. Chapatis were removed from the warming drawer, torn into halves and each half placed on a preheated china plate and set before a panelist. As soon as the chapatis were sufficiently cool, each panelist sniffed his chapati 2-3 times while it was still on the plate; turned the chapati over and sniffed again; and picked it up and smelled the inside. Each member recorded on a printed form (Form 2, Appendix) the amplitude or over-all impression of the aroma, the individual aromatics perceived in order of their appearance and the intensity of each aromatic.

Each panel member then tasted thumbnail-sized pieces from both the center and the edge of the chapati half. Again the amplitude, the individual flavor components perceived in order of appearance and the intensity of each component were recorded. The aftertaste was reported about 1 minute after swallowing. Demineralized distilled water at room temperature was used as a mouth rinse when needed.

At this point, departure was made from the usual flavor profile method. The panelists examined their samples with reference to certain desirable chapati characteristics (Form 2, Appendix), and the session was ended without the round-table discussion of findings that is usually a part of flavor profile analysis. Discussion was eliminated because it has been reported as a possible source of bias (Hall, 1958).

Following each formal panel meeting, the panel leader tabulated the data. On February 23, 1970, after all scheduled panel sessions had been completed, a summary of the data was presented to the panel. At this open meeting the panel leader's interpretation of terminology used by the panelists was discussed.

RESULTS OF THE PILOT STUDY

Data acquired during the pilot study do not appear in tabular form, because the initial work primarily was orientative in nature with respect to the major study. Differences in the results of the pilot and major studies are presented in the discussion, however, and summarized in Table 11 of the Appendix.

Controls

Organoleptic Properties of the Control Flour. Gaines wheat flour was described as a creamy colored flour with reddish-tan bran. It was both soft and sandy to the touch. Flour aromatics were wheaty, starchy, green and oxidized. A fleeting rubbery characteristic also was noted. Both sweet and lingering bitter tastes and astringency were identified in the flavor.

Use Properties of the Control Flour. The dough prepared from Gaines wheat flour was creamy in color. During mixing, dough formation was rapid, and faint flour aromatics were noted. The newly formed dough was inelastic, yet soft and pliable. After resting, the dough was elastic, though somewhat sticky, as a result of which more than 1 g of flour sometimes had to be used during rolling. During cooking, the chapatis browned slowly and lightly and emitted toasted wheat aromatics, but puffed slightly less than fully.

Eating Qualities of the Control Chapatis. The control chapatis were creamy colored with many light brown spots on the outer surfaces. They were pliable, but somewhat floury on the outside and rough to the touch, due to the extra flour that was used during rolling. They were not quite fully puffed and slightly gummy on the inside. The amplitudes of both aroma and flavor were described as low. Chapati aromatics were toasted wheat, starchy and raw doughy, the toasted wheat aromatics being more intense than the others. Sweet and bitter tastes were observed in the flavor along with gumminess in texture. Sweet and toasted wheat characteristics were sometimes observed in the aftertaste.

Fish Protein Concentrate (FPC) Series

Organoleptic Properties of the Supplement and Flour Blends. The 100% FPC was described as grayish-green in color and powdery in appearance. Its aroma was clammy and alkaline. Its flavor was composed of fishy, alkaline and lingering clammy aromatics, as well as salty taste and sensations of mouth-fullness, grittiness and drying.

FPC was definitely detectable in the flavor of all the supplemented raw flours and in the aroma of the 15% blend. Clammy aromatics were detected initially in the aroma of the 5 and 10% blends, but seemed to dissipate quickly. As supplementation levels increased from 5 to 10 to 15%, the flours were progressively more powdery and grayish-green in color, and the typical FPC aromatics and in-the-mouth sensations in the flavor became more intense.

Use Properties of the Flour Blends. All supplemented doughs were darker than the control. The aroma of FPC was noticeable during the first mixing of all the doughs, but subsequently diminished and was not apparent in any of the chapati samples during cooking. Because of the highly absorptive nature of FPC, its presence initially stiffened all of the supplemented doughs, particularly the 15% dough, which was described as dry and crumbly. After the resting period, however, the supplemented doughs were slacker than the control and difficult to handle. FPC-supplemented chapatis tended to stick to the griddle during cooking.

Eating Qualities of the Supplemented Chapatis. Increments in FPC yielded chapatis that were progressively darker, more crusty on the outside, gummier on the inside and less sweet and wheaty. The 5% chapati samples were not perceptibly "off" in flavor, but had a suppressed wheat character. The alkaline and clammy aromatics of the FPC were detectable in the 10% chapati samples, which were characterized as poorly puffed and having gritty integers and suppressed wheat character. The 15% supplemented chapatis were eliminated from further examination after initial screening, because of extreme "off-ness" in both aroma and flavor together with an atypically dark appearance and leathery texture.

Cottonseed Flour (CSF) Series

Organoleptic Properties of the Supplement and Flour Blends. The raw CSF was described as greenish-tan, both powdery and particulate in appearance and interspersed with black specks. Initially, the aroma of the CSF was characterized by an oily-gassy-rubbery aromatic. Its flavor was marked by the same aromatic and was further described as oxidized, salty, sweet, green-vegetation-like, bitter and astringent, accompanied by a drying sensation and salivation. The CSF caused a tongue bite and belching. During the 7 weeks between initial and final examinations, the flour seemed to "air out". The rubbery aromatic was lost, and the oily and gassy aromatics diminished in intensity.

CSF was detectable in all of the supplemented raw flours. It darkened the 5 and 10% flour blends and imparted greenish-tan color to the 15% blend. The black specks present in the CSF were noticeable in the 10 and 15% flour blends. The full aroma and flavor spectra of CSF were observed in the 10 and 15% raw flours, whereas the aroma and flavor of the 5% sample were redolent of only the greenish and not the so-called oily-gassy-rubbery aromatic.

Use Properties of the Flour Blends. The use of CSF as a supplement altered the appearance of the chapati dough. At all levels of supplementation CSF was detectable by the presence of black specks. CSF aroma was detectable during the mixing of the 10 and 15% doughs, but it quickly dissipated and was not noticeable during the cooking process. All supplemented doughs were slightly drier than the control during mixing, but after mixing they were stickier than the control. After resting, the 10 and 15% supplemented doughs were still somewhat sticky, and all supplemented doughs were less elastic than the control. None were difficult to handle. No effects of supplementation on the cooking process were observed.

Eating Qualities of the Supplemented Chapatis. Supplementation with CSF did not affect the appearance of the 5 and 10% supplemented chapatis. Supplementation at the 15% level produced greenish-tan colored chapatis in contrast to the creamy-white control, and the black specks from the CSF were noticeable. CSF aroma and flavor were readily apparent only in the 15% supplemented chapatis. The 5% chapatis contained the greenish but not the oily-gassy-rubbery CSF aromatic in the aroma and flavor and were sweeter and fuller in aroma and flavor than the other supplemented chapatis or the control. The 10% supplemented chapatis were fully redolent of CSF in aroma as well as flavor, but at such a low level that repeated examinations were required to detect it. The 15% samples also were redolent of CSF in aroma and flavor, but at a much higher level of intensity. Belching, which implies indigestion, resulted from the tasting of all chapatis made from flours containing CSF supplementations.

RESULTS OF THE MAJOR STUDY

Composite flavor profiles of the control chapati and all 9 variations of supplemented chapatis appear in the Appendix, Tables 4-7. The profile characteristics introduced by chapati supplementation with FPC, CSF and SPC are described in Table 8 of the Appendix. Tables 9 and 10, respectively, are summaries of the changes in the use properties of the control flour and in the eating qualities of the control chapati introduced by increments in supplementation with FPC, CSF and SPC.

Controls

Organoleptic Properties of the Control Flour. Gaines wheat flour was described as heterogeneous in appearance, containing both creamy colored flour particles and reddish-tan bran. It was both soft and sandy to the touch. Flour aromatics were typically wheaty, branny, dusty and starchy, although a green character note also was observed. The Gaines flour was definitely sweet in taste and possibly bitter.

Use Properties of the Control Flour. The dough prepared from Gaines wheat flour was creamy in color. During mixing, dough formation was rapid and aromatics typical of the flour were noted. The newly formed dough was inelastic, yet soft and pliable. After resting, the dough was elastic and easy to handle and roll. During cooking, the chapatis browned slowly and lightly, puffed fully and rapidly and emitted toasted wheat aromatics.

Eating Qualities of the Control Chapatis. The composite flavor profile of the control chapati appears in Table 4 of the Appendix. The control chapatis were creamy in color with many light-brown spots. They were soft and pliable, fully puffed, well-cooked on the inside and easily chewed. The amplitudes of both the aroma and flavor were described as low to slightly higher than low. Toasted wheat aromatics predominated in the aroma, although starchy and raw doughy character notes also were present at lower intensity levels. The flavor of the control chapatis was typically sweet and toasted wheaty, with less intense starchy and raw doughy aromatics also being observed. Wheaty and sweet lingered into the aftertaste at threshold levels.

Fish Protein Concentrate (FPC) Series

Organoleptic Properties of the Supplement and Flour Blends. The 100% FPC was described as a fine powdery substance, yellowish-tan in color. Predominant character notes in its aroma were fishy and alkaline. Other descriptive terms used were pungent, mercaptan, dusty, solvent-y and oxidized. The flavor of the FPC was composed primarily of fishy aromatics, as well as salty, bitter and sweetish tastes and sensations of grittiness, tongue bite and drying. Other flavor components included oily, starchy, albuminous and sulfurous.

The presence of FPC was definitely detected in the flavor of all the supplemented flours and in the aroma of the 15% blend. Some FPC aromatics also were detected by some of the panelists in the aroma of the 5 and 10% blends. As supplementation levels increased from 5 to 10 to 15%, the flour blends became progressively darker and more powdery than the control, and the FPC aromatics in the flavor became more intense.

Use Properties of the Flour Blends. The 5 and 10% supplemented doughs were darker than the control, and the 15% supplemented dough was described as grayish in color (Table 9, Appendix). FPC aromatics were detected in all of the doughs, but diminished during mixing and were detected only on one occasion in the 15% supplemented dough during rolling and cooking. All of the supplemented doughs were drier and stiffer than the control during mixing, whereas after resting all were much less elastic than the control. The dough supplemented with 15% FPC was so slack that it was difficult to roll. During cooking, the 10 and 15% supplemented chapatis browned much more rapidly than the control and did not puff fully.

Eating Qualities of the Supplemented Chapatis. Composite flavor profiles of the FPC-supplemented chapatis appear in Table 5 of the Appendix. All chapatis supplemented with FPC were described as darker in color than the control, gummy on the inside, poorly puffed and leathery, dry and gritty on the outside (Table 10, Appendix). Supplementation with FPC at all levels suppressed the amplitudes of the chapatis in both aroma and flavor. FPC supplementation also had a suppressing effect on toasted wheat aromatics. The intensity of toasted wheat character was decreased in the aroma and flavor of all supplemented chapatis, and the wheaty characteristic was absent in the aroma and flavor of the 15% sample. The intensity of the starchy character present in the aroma and flavor of the control chapatis was decreased in the aroma of all supplemented chapatis. The raw doughy aromatics characteristic of the control were decreased in the aroma and perhaps in the flavor of all supplemented chapatis. Chapatis supplemented with FPC at all levels were less sweet than the controls. FPC aromatics were in themselves detectable in the aroma and flavor of all supplemented chapatis. The aftertaste of the 10 and 15% supplemented chapatis differed from the control in that wheaty and sweet character notes were absent and FPC aromatics were present.

Cottonseed Flour (CSF) Series

Organoleptic Properties of the Supplement and Flour Blends. The CSF was sandy in texture and heterogeneous in appearance. It was composed of both tan and darker brown particles and contained black specks. The aroma of the CSF was typified by a crude resinous character variously described as paint-like, gassy, rubbery, green, fir-tree-like, oxidized and sulfurous. Other terms used to describe its aroma included pungent, dusty, brown-paper-bag-like, solvent-y, albuminous and mercaptan. The same crude resinous aromatics predominated in the flavor of the CSF. Additional elements of its flavor included bitter, salty and sweetish tastes and grittiness.

CSF was detectable in all of the supplemented flour blends. Supplementation at the 10 and 15% levels darkened the flours, and at all levels of supplementation the black specks present in the CSF were noticeable. The 10 and 15% supplemented flours were fully CSF in character, whereas the 5% blend was redolent of only some of the CSF aromatics and was sweeter and more wheaty than the other blends or the control.

Use Properties of the Flour Blends. The black specks present in the CSF were noticeable in all of the supplemented doughs (Table 9, Appendix). The aromatics of CSF were detectable in all supplemented doughs but diminished in intensity during mixing and were detected only on one occasion in the 15% supplemented dough during rolling and cooking. All supplemented doughs were drier and stiffer than the control during mixing. After resting, the 15% dough was slightly sticky, and all doughs were less elastic than the control. None were difficult to roll, however. During cooking, the supplemented chapatis seemed to puff as well as the control.

Eating Qualities of the Supplemented Chapatis. Composite flavor profiles of the CSF supplemented chapatis appear in Appendix, Table 6. Chapatis supplemented with CSF at all levels were darker in appearance and less fully puffed than the control, and gummy on the inside (Table 10, Appendix). In addition, the black specks of the CSF were noticeable. CSF supplementation seemed to increase the amplitudes of aroma of the 5% supplemented chapatis, may have decreased the amplitude of aroma of the 10% sample and otherwise decreased amplitudes of both aroma and flavor. The intensity of toasted wheat aromatics, especially in the flavor, was decreased by CSF supplementation at all levels. The starchy and raw doughy aromatics present in the control were decreased in intensity in the aroma and perhaps in the flavor of all supplemented chapatis. The sweetness of the control was relatively unchanged by CSF supplementation, although it may have been slightly higher in intensity in the 5% sample. The aromatics of CSF were probably detectable in the aroma and flavor of all supplemented chapatis. The presence of CSF altered the aftertaste of all supplemented chapatis. The wheat characteristic was absent, and sweet was absent except perhaps in the 5% sample. CSF aromatics were fully present in the aftertaste of only the 15% supplemented chapatis.

Soy Protein Concentrate (SPC) Series

Organoleptic Properties of the Supplement and Flour Blends. The SPC was reddish-tan in color and sandy in texture. Its aroma was described as primarily legumy, resinous, solvent-y and dusty in character. Other descriptive terms used were cardboardy, wheaty and caramelized. The flavor of SPC was composed of predominant legumy aromatics, bitter taste and sensations of grittiness and drying. Other aromatics observed were resinous, cardboardy, branny, toasted, starchy and dusty, and it was also described as sweetish.

Supplementation with SPC had little effect on the appearance of any of the flour blends, although it may have darkened them slightly. The 15% supplemented flour was, however, noticeably sandier in texture than the other blends or the control. Only some of the character notes associated with SPC were observed in the 5% flour blend. The 10% supplemented flour was typical of SPC in flavor, but its aroma was redolent of only some of the SPC aromatics. At the 15% level of supplementation, the complete aroma and flavor spectra of SPC were detectable.

Use Properties of the Flour Blends. Supplementation with SPC did not affect the appearance of any of the doughs (Table 9, Appendix). SPC aromatics were detectable in all of the supplemented doughs, but diminished in intensity during mixing and were not noticeable in any of the doughs during rolling or cooking. The mixing properties of the doughs were markedly affected by SPC supplementation. The 5% dough was drier and stiffer than the control, and the 10 and 15% flours would not form doughs until an additional 1 ml of water per 1 g of SPC was added. All doughs after resting were less elastic than the control, but not difficult to roll. The 15% dough did, however, have a sandy texture. During cooking, all supplemented chapatis puffed well but browned more extensively than the control. The cooked 10 and 15% supplemented chapatis were dark and crisp on the outside.

Eating Qualities of the Supplemented Chapatis. Composite flavor profiles of the SPC-supplemented chapatis appear in Table 7 of the Appendix. SPC altered the appearance of only the

10 and 15% supplemented chapatis (Table 10, Appendix). They were darker in color than the control and were dry and crisp in spots on the outside. Amplitudes of aroma and flavor may have been decreased by SPC supplementation at all levels. The toasted wheat character of the 5% supplemented chapatis was similar to that of the control, but might have been decreased in intensity in the aroma and flavor of the 10 and 15% samples. Starchy aromatics present in the control may have been increased in the aroma of all supplemented samples, whereas raw doughy aromatics were less intense in the aroma and possibly the flavor of the supplemented samples. Supplementation with SPC had no effect on the sweetness of the chapatis, and the aromatics of SPC were detectable in both aroma and flavor at the 15% level only. In the aftertaste, SPC supplementation may have decreased the wheaty character in all samples and decreased sweet in the 15% sample. SPC aromatics may have been detectable in the aftertaste of both the 10 and 15% supplemented chapatis.

DISCUSSION AND CONCLUSIONS

Performance comparisons between each type of supplemented flour blend and the control appear in Table 11 of the Appendix. Comparisons include each use property and eating quality assessed in both studies. More detailed flavor profile comparisons of aroma and flavor derived from the major study are presented in Appendix, Table 12. All comparisons in both tables are based on similarity to (+) or difference from (-) the control. An additional symbol (?) has been used where small differences were occasionally found but may have been attributable to inherent variables in the studies. Possible unintentional sources of variation will be discussed.

Data from both the pilot and major studies indicate that supplementation with FPC at all levels affected most of the use properties observed (Table 11, Appendix). Differences from the control were noted in the appearance and flavor of all FPC flour blends, and in the aroma of the 15% blend. The presence of FPC was sometimes observed in the aroma of the 5 and 10% blends. FPC-supplemented doughs differed from the control in appearance and aroma during mixing as well as in mixing, handling and cooking properties. These differences were apparent at all levels of supplementation in both studies, with the exception of the cooking properties of the 5% sample in the major study, which were similar to those of the control. Aromatics emitted during the cooking of the supplemented chapatis were similar to those of the control, except possibly those of the 15% sample.

FPC supplementation affected all of the eating qualities studied except apparent digestibleness (Table 11, Appendix). The presence of FPC altered the appearance, aroma and flavor of all supplemented chapatis, as indicated by comparison of flavor profiles for the FPC-supplemented chapatis and the control (Table 12, Appendix). Additionally, FPC-supplemented flours produced chapatis that were poorly puffed, gummy inside and leathery, dry and gritty on the outside (Table 10, Appendix).

The results of both studies indicate that CSF supplementation affected fewer of the use properties studied than did FPC supplementation (Table 11, Appendix). Differences from the control were observed in the appearance of all flour blends, and in the aroma and flavor of the 10 and 15% blends. Differences occasionally were reported in the aroma and flavor of the 5% blend. Doughs supplemented with CSF were different from the control in appearance, aroma during mixing (with the possible exception of the 5% dough) and mixing properties, and may have been different in handling properties. CSF supplementation seemed to have no effect on the cooking properties of the doughs, although in the larger study reports from the panel indicated that all CSF-supplemented chapatis were less fully puffed than the control. Supplementation with CSF had no discerned effect on the aromatics emitted during cooking, except possibly at the 15% level of supplementation.

Data from the major study indicate that the presence of CSF affected the appearance of all supplemented chapatis, although in the pilot study the 5 and 10% samples did not differ from the control. Supplementation with CSF definitely affected chapati aroma and flavor at the 15% level, and was sometimes reported to affect aroma and flavor at the 5 and 10% levels. According to the results of the major study, CSF supplementation affected the texture of all chapatis. During the pilot study, however, no such differences were observed. The apparent indigestibleness of all supplemented samples reported in the pilot study was not observed in any of the samples in the major study.

Supplementation with SPC had the least effect of the 3 supplements on the use properties of the flour blends (Table 11, Appendix). There was only a slight difference from the control, if any, in the appearance of the supplemented flours. SPC definitely affected both flour aroma and flavor at the 15% level only, and just flour flavor at the 10% level. At the 5% level effects on aroma and flavor were observed occasionally. SPC supplementation had no effect on the appearance or cooking aroma of any of the samples. It did, however, affect the aroma emitted during mixing and the mixing properties of all samples. Effects on handling were questioned except at the 15% level of supplementation, where marked effects were observed. The cooking properties of both the 10 and 15% samples differed from the control.

Supplementation with SPC altered the appearance of the 10 and 15% supplemented chapatis. It definitely affected both the aroma and flavor of only the 15% sample and the flavor of the 10% chapati, although the presence of SPC may have altered the aroma of the 10% sample and both the aroma and flavor of the 5% sample. The texture of both the 10 and 15% supplemented chapatis differed from the control.

The performance comparisons that have been presented indicate slight discrepancies in results between the 2 studies, and some differences in findings among panel members. Both types of differences may be accounted for by inherent variables in the studies. First, a certain amount of human error was unavoidable because of the subjective nature of flavor profile analysis. This source of variation was, however, reduced by extensive training of the panelists.

A second source of variation was inherent in the control flours (95.8 and 97% extraction). Since they were prepared from wheat which is a natural product, the 2 would be expected to differ somewhat in aroma and flavor. The 95.8% extraction Gaines wheat flour used during the pilot study was in fact less wheaty and more green, oxidized and bitter in character than the 97% extraction Gaines flour used during the major study.

A third unintentional variable introduced in these studies was the lack of uniformity of the flour blends. During the major study, there was occasionally as much variation in flavor profiles of halves of the same supplemented chapati as in profiles of chapatis supplemented at different levels with the same supplement. The source of variation could have been inexpertise on the part of the panelists, but it seems probable that it should be attributed to uneven distribution of supplement particles within the flour blends. This explanation is based on 3 facts: (1) no such wide variation was observed in flavor profiles of the control chapatis, (2) the nitrogen contents (Table 2, Appendix) of some of the flour blends indicate uneven distribution of protein and (3) the phenomenon of particle segregation is well known to persons in the milling, cosmetic and pharmaceutical industries who have been concerned with the mixing and blending of powders of different density and particle size (Hersey, 1970 and Lloyd _et al._, 1970). If such segregation did occur, and if it cannot be prevented, it should be considered in the performance evaluation of the test flours, since it would occur either in commercially distributed flour blends or in blends prepared in the home.

A fourth source of variation was evinced by the observation that the CSF seemed to "air out" during the course of the pilot study. The loss of volatiles, indicated by the reduction in crude resinous character, also may have been related to the fact that no indigestion from CSF was reported during the major study, since the same CSF was used in both studies. It would thus appear that the organoleptic properties of the supplements are themselves subject to change, even during cold storage.

A fifth source of variation existed between the pilot and major studies. Different persons prepared the chapatis; slightly different preparation procedures were used; and the chapatis were held in a warming device before organoleptic work began in the major study, whereas they were examined immediately after their preparation in the pilot study.

Based upon the reported effects of flour supplementation, inferences can be drawn with reference to potential product acceptability by the intended consumer. First, however, the relevance of this performance assessment of the samples to consumer acceptance should be clarified.

The criterion for evaluation used in the 2 studies (i. e., no difference from the control) seems rather strict for 2 reasons. First, the sample examinations were carried out under controlled conditions conducive to the perception of small changes in the organoleptic properties of a product. Secondly, chapatis are sometimes prepared with salt and are normally consumed as a sort of edible utensil used to scoop up wet foods. In such a situation the off-flavor of a supplement might be corrected by salt or masked by the flavor of the adjunct foods. Chapatis are a product that already has consumer acceptance, and as Matz (1960) noted, any change in an already acceptable product must be so slight as not to alter its characteristics. Furthermore, the masking effect described is unpredictable until *in situ* product testing data are available. Thus it is best to accept only those supplemental levels that are not responsible for marked deviations from the control in use properties and eating qualities.

Consumer behavior and known desirable chapati characteristics may be used to predict which performance differences will most adversely affect the acceptability of the supplemented flour blends. Use properties and eating qualities are both food product attributes that are observed by consumers, and any deviation in either alerts the consumer. Handling properties sometimes can be adjusted by the consumer, however, and "off-odors" observed during preparation may be forgotten if subsequently the flavor of the product is "normal". Therefore, the eating qualities of the product make the final and probably the greatest impression on the consumer, and are apt to have the greatest effect on product acceptability.

The literature gives some indication of desirable eating qualities of chapatis. As reported earlier, a chapati should be creamy colored and speckled with brown spots, soft and pliable, well puffed, well cooked on the inside and easily chewed, as well as caramel and sweetish in flavor (Ahmad, 1960, Murty *et al.*, 1963 and Sinha, 1964). It should not be leathery, gritty, brittle or gummy, and probably should not have a fishy aroma or flavor, since according to Haq (1967) the people of Pakistan do not like fish.

With reference to FPC, data from both the pilot and major studies indicate that the 5, 10 and 15% supplemented flours had atypical use properties. Among other things, all flours and doughs were darker than the creamy colored control, the doughs were stiffer than the control during mixing but slack and difficult to handle after resting and FPC aromatics were detectable during mixing. Even though the consumer might not notice or object to the color differences and might be able to adjust the water absorption, she would be apt to object to the handling properties of the doughs and be alerted by the FPC aromatics, particularly if fish odor were offensive to her.

The eating qualities of all FPC-supplemented chapatis also were atypical. The supplemented samples were darker than the creamy colored control, leathery to crusty on the exterior rather than pliable like the control, poorly puffed, gummy on the inside and not easy to chew. All were less sweet and wheaty than the control, and the 15% supplemented chapati had no wheat aromatics, which are part of the identity of the control chapati (Table 4, Appendix). Additionally, the 10 and 15% supplemented chapatis and probably the 5% as well were redolent of FPC in both aroma and flavor. Regardless of whether or not the typical West Pakistani consumer likes fish, fishy aromatics are not a part of "normal" chapati identity and probably would adversely affect chapati acceptability. Thus the 10 and 15% FPC-supplemented chapati flours, and probably the 5% blend as well, appear to be potentially unacceptable to the native consumer.

The appearance of the flours and doughs is the use property that probably would most limit the acceptability of the CSF blends. The 10 and 15% supplemented flours and doughs (and probably the 5%) were darker than the control and contained black specks. The Indian student assisting with chapati preparation believed that West Pakistani women would not use either the 10 or 15% supplemented flour because of the connotation of the foreign particles in the doughs. Other atypical use properties that could adversely affect acceptability include initial dryness and subsequent inelasticity of the doughs, and the presence of CSF aromatics in the 10 and 15% raw flours and probably in all of the doughs during mixing. The atypical mixing and handling properties of the doughs might not be noticed by the consumer, however, since none of the doughs were difficult to roll. CSF aromatics also might not adversely affect the acceptability of the flour blends, since CSF aroma is not completely dissimilar to wheat flour character.

Appearance seems to be the most limiting of the eating qualities with respect to the acceptability of CSF-supplemented chapatis. The 15% chapati samples in both studies and all samples in the major study were darker than the control and contained black specks. The belching that was observed during the pilot study also might limit the acceptability of all CSF-supplemented chapatis, as it would be apt to be noticed by the consumer.

This gaseity was not reported during the major study, however. Other factors that might limit the use of CSF as a chapati supplement include the gumminess, less than full puffing and suppressed wheat character reported for all CSF-supplemented chapatis evaluated during the major study. The aroma and flavor of CSF would appear to limit chapati acceptability only at the 15% level, but even at this level it might not be a limiting factor if it were not objectionable to the consumer.

The use of this particular CSF as a chapati supplement seems to be contraindicated because of undesirable appearance factors and the apparent indigestibleness observed. Another CSF which did not have these properties was, however, examined by the 6-member flavor profile panel. It was a non-heat-denatured glandless CSF produced through the collaboration of personnel from the National Cottonseed Products Association, the SURDD/USDA at New Orleans, the Oilseed Products Research Center, Texas A & M University and the Crown Iron Works Company. It was lighter in color and less crude resinous in character than the other CSF, contained tiny black specks that were noticeable to only half of the panel and did not produce any gaseousness in panel members. Although time did not permit a performance evaluation of this CSF, it might have greater acceptance potential as a flour supplement for chapatis than the CSF used in this study.

The use properties of SPC-flour blends most adversely affected the acceptability of the 10 and 15% samples. All doughs were abnormally dry, and the 10 and 15% supplemented flours would not form doughs until additional water was added to the basic recipe. The consumer could and probably would adjust the water absorption, however. All supplemented doughs were redolent of SPC during cooking, but this abnormality might be forgotten by the consumer, particularly at the 5% level since the 5% supplemented chapati was not definitely off in aroma or flavor. The presence of SPC at all levels of supplementation reduced the elasticity of the doughs, but this effect of supplementation might not be noticed by the consumer since none of the doughs were difficult to handle. The 15% supplemented dough had a sandy texture, however, which would alert the consumer since chapati dough is typically kneaded by hand. During cooking, both the 10 and 15% supplemented chapatis browned more extensively than the control. Cooking time and/or temperature could be adjusted, but possibly at the sacrifice of a well-cooked chapati inside.

SPC supplementation affected the appearance and texture of both the 10 and 15% chapati samples, which were described as dark, dry and crisp. These atypical characteristics would be apt to adversely affect acceptability if creamy colored, pliable chapatis are desirable. An adjustment in the water absorption might eliminate the dryness and crispness but would not alter the abnormal color. SPC aroma and flavor might be expected to adversely affect the acceptability of the 15% supplemented chapati and possibly that of the 10% sample as well.

Based upon both use properties and eating qualities, it would be reasonable to believe that the 15% SPC-supplemented flour would be unacceptable to the consumer. The 10% blend would be apt to be unacceptable unless water absorption could be adjusted effectively and atypical chapati color and flavor would not be objectionable. SPC supplementation at the 5% level appeared not to adversely affect the potential acceptability of the flour blend.

The conclusions reached are valid only for the particular test flours studied. There are many different FPC, CSF and SPC products available that vary widely in organoleptic and functional properties. One such CSF has been mentioned. Furthermore, these conclusions represent only part of the information needed to successfully develop a protein supplemented flour(s) for chapati preparation in West Pakistan.

The purpose of the AID project, of which this study is a part, is to develop not only an acceptable product(s), but also a flour(s) that represent a substantial nutritional improvement over unsupplemented chapati flour. Table 13 of the Appendix is a comparison of the essential amino acid compositions of the test flours to the Food and Agriculture Organization (FAO) provisional pattern (FAO, 1957). This FAO pattern was used as a basis for comparison to give an indication of the relative amounts of essential amino acids present. It is assumed that a hypothetical protein containing amino acids according to the pattern would be a protein of high biological value.

In comparison to the provisional pattern, data presented in Table 13 indicate that methionine, lysine and isoleucine are the first, second and third limiting amino acids of the Gaines wheat flour. Although all supplements are higher in lysine than the control, all supplemented blends may not have had an improved amino acid pattern. For example, based on mg of amino acid/g nitrogen, CSF is lower in isoleucine and methionine than the Gaines flour, and SPC is lower in methionine than the Gaines. Thus the blends supplemented with either CSF or SPC contained less methionine per gram of nitrogen than the control flour. Supplementation with FPC seems to most improve the amino acid pattern of the Gaines wheat flour; it contained larger amounts of methionine, lysine and isoleucine per g of nitrogen than the control flour. However, whether or not any of the supplemented test flours represents a real nutritional improvement over the unsupplemented wheat flour can be confirmed only by appropriate tests on animals and humans.

RECOMMENDATIONS

Two of the reported disadvantages of the flavor profile method of analysis are the extensive training required for the 4-6 panelists that normally are used (Caul, 1957), and the bias that may be introduced during the open panel sessions (Krum, 1955). During the course of this research, 2 slightly modified methods of flavor profile analysis were employed. A 2-member panel was used for the pilot study, and discussion following sample examination was eliminated during the major study. Based upon the similarity of results obtained from the pilot and main studies, 2 recommendations regarding flavor profile analysis methodology are made.

First, the use of round-table discussion as an integral part of flavor profile analysis is recommended. Comparison of the results of the pilot and major studies (Table 11, Appendix) reveals few differences between the 2, and most of these probably can be explained by uncontrolled variables. Thus it would seem that discussion was not a source of bias. Furthermore, in the absence of discussion during the major study, the panel leader alone had to interpret the terminology used by each panel member. This interpretation was necessary, in spite of the panelists' previous orientation to chapatis, because of the variation within the supplemented test flours and the subsequent frequent introduction of new character notes. Although discussion of terminology was held approximately 5 weeks after the conclusion of formal panel sessions, by this time the panelists were vague when asked to explain some of the terms they had used to depict minor character notes. Thus this study has revealed no disadvantage of discussion, and has indicated the need for round-table discussion immediately following sample examination.

Secondly, panel size apparently had no effect on results. Similar conclusions can be drawn from the 2-member and 6-member panel data. It would seem, then, that 4 persons is not necessarily the minimum size requirement for a flavor profile panel. However, if as few as 2 panelists are to be used for flavor profile work, some risk is inherent, since the incapacitation of just 1 of the panelists would halt panel operation. Nevertheless, a reduction in the required panel size would facilitate the use of flavor profile analysis research, when 4 or more trained panelists are not available.

SUMMARY

The 10 and 15% FPC-supplemented chapati flours and probably the 5% blend appeared to be potentially unacceptable to the native consumer. All flour blends had atypical and probably undesirable use properties. FPC aromatics were detected in all supplemented chapatis, and were more intense at the 10 and 15% levels of supplementation than at the 5% level. Chapatis prepared from the 15% supplemented blend had no wheat identity and were atypical in color and texture. The 5 and 10% supplemented chapatis, although somewhat wheaty in character, were also atypical in color and texture, which would be apt to adversely affect their acceptability and thus that of the flour blends. Furthermore, the 10% and possibly the 5% chapati samples would be unacceptable if FPC aroma and flavor were objectionable to the consumer.

Undesirable appearance factors seemed to contraindicate the use of the particular CSF studied as a chapati supplement. CSF-supplemented flours, doughs and chapatis all contained noticeable black specks, the connotation of which would be apt to adversely affect the acceptability of all flour blends. Furthermore, belching sometimes resulted from the tasting of chapatis prepared from flours containing CSF supplementation. The aroma and flavor of CSF appeared to limit chapati acceptability only at the 15% level, however, and even at this level might not be a limiting factor if it were not objectionable to the consumer.

Based upon both atypical and probably undesirable use properties and eating qualities, it was concluded that the 15% SPC-supplemented flour would be unacceptable to the West Pakistani consumer. The 10% flour blend would be apt to be unacceptable unless water absorption could be effectively adjusted by the consumer and atypical chapati color and flavor would not be objectionable. SPC supplementation at the 5% level appeared not to adversely affect the acceptability of the flour blend.

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APPENDIX

Form 1. Flavor profile panel schedule.

Date		Products examined
December	8	Control chapati
	9	Control chapati
	10	5% FPC chapati, 10% FPC chapati
	11	10% FPC chapati, 15% FPC chapati
	12	15% FPC chapati, 5% FPC chapati
	15	Control chapati, 5% CSF chapati
	16	10% CSF chapati, 15% CSF chapati
	17	5% CSF chapati, control chapati
	18	No panel
	19	15% CSF chapati, 10% CSF chapati
January	5	CSF raw flour series (Gaines; 5, 10, 15 and 100% CSF)
	6	CSF raw flour series from pilot study (Gaines; 5, 10, 15 and 100% CSF)
	7	15% CSF chapati, 100% CSF raw flours (Texas A & M and National Cottonseed Products Association)
	8	No panel
	9	15% CSF chapati (prepared with flour from pilot study)
	12	FPC raw flour series (Gaines; 5, 10, 15 and 100% FPC)
	13	Control chapati, 5% SPC chapati
	14	5% SPC chapati, control chapati
	15	10% SPC chapati, 15% SPC chapati, SPC raw flour series (Gaines; 5, 10, 15 and 100% SPC)
	16	15% SPC chapati, 10% SPC chapati

Form 2. Chapati analysis record.

Name

Date

Product

Amplitude of aroma: Aroma:	Desirable chapati characteristics: (check, or list if different)
	_____Creamy color, many light brown spots
	_____Uniform thickness
Amplitude of flavor: Flavor:	_____Soft and pliable
	_____Fully puffed
	_____Inner layer well cooked
Aftertaste:	_____Easily chewed

Table 1. Sieve analyses of Gaines wheat flour used for chapati preparation.

Microns	U.S. Std.	95.8% extraction flour used in pilot study	97% extraction flour used in major study		
μ	overs		Batch 1	Batch 2	Batch 3
1410	14	0	0	0	0
351	45	16.5	13.0	14.6	17.0
177	80	61.0	62.5	55.0	57.0
0	pan	22.5	24.5	30.4	26.0

Table 2. Proximate analyses of test flours and supplements.

Sample	% Nitrogen	%N x 6.25	% Moisture	% Ash
97% extraction Gaines Wheat Flour	1.536	9.6	8.9	1.5
FPC[a]	12.768	79.8	4.5	-
5% FPC	2.208	13.8	8.2	2.1
10% FPC	2.752	17.2	8.7	2.6
15% FPC	3.488	21.8	8.1	3.2
CSF[b]	9.616	60.1	6.8	-
5% CSF	2.016	12.6	9.0	1.8
10% CSF	2.400	15.0	8.6	2.1
15% CSF	2.800	17.5	8.6	2.4
SPC[c]	10.704	66.9	4.7	-
5% SPC	2.080	13.0	8.4	1.6
10% SPC	2.592	16.2	8.6	1.7
15% SPC	2.992	18.7	8.2	1.8

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Table 3. Amino acid analyses of Gaines wheat flour and supplements.

Amino acids (g/100g sample)	97% extraction Gaines Wheat Flour	FPC[a]	CSF[b]	SPC[c]
Alanine	0.364	5.665	2.161	3.055
Arginine	0.480	5.518	7.198	4.787
Ammonia	0.221	0.980	1.151	1.183
Aspartic acid	0.582	8.852	5.333	7.619
Cystine (by oxidation)	0.251	0.729	1.044	1.022
Glutamic acid	2.757	13.161	12.074	12.974
Glycine	0.416	6.197	2.301	2.894
Half cystine	0.119	0.320	1.308	1.277
Histidine	0.204	1.387	1.568	1.652
Isoleucine	0.309	3.590	1.639	3.038
Leucine	0.636	6.771	3.343	5.702
Lysine	0.301	6.805	2.402	4.198
Methionine	0.098	2.403	0.740	0.836
Methionine (by oxidation)	0.153	2.172	0.861	0.941
Phenylalanine	0.373	3.352	3.058	3.473
Proline	0.889	3.661	2.082	3.426
Serine	0.453	4.112	2.539	3.654
Threonine	0.293	3.822	1.848	2.700
Tyrosine	0.287	2.642	1.778	2.455
Valine	0.467	4.170	2.449	3.299

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Table 4. Composite flavor profile of the control chapati.

Amplitude of aroma: 1 to 1+			
Aroma:			
1 to 1+	Toasted wheat =	wheaty (grainy) floury (dusty) branny (feedy)	+ cooked character carbonyl caramelized toasted burned
)(	Starchy (clothy, heated starch, cream style corn)		
)(to 1	Raw doughy (glutenous, alkaline-soapy)		
Amplitude of flavor: 1 to 1+			
Flavor:			
)(to 1	Sweet		
1 to 1+	Toasted wheat =	wheaty (grainy) floury (dusty) branny (feedy)	+ cooked character carbonyl (bitterish) caramelized (sweetish) toasted burned (sourish)
)(	Starchy		
)(	Raw doughy (raw starchy, glutenous, sour)		
Aftertaste:			
)(	Wheaty (toasted, branny)		
)(	Sweet		

Intensity key:

)(threshold

1 slight

1+ between slight and moderate, closer to slight.

Table 5. Composite flavor profiles of FPC[a]-supplemented chapatis.

5% FPC		10% FPC		15% FPC	
Amplitude of aroma:)(to 1+		Amplitude of aroma:)(+ to 1		Amplitude of aroma: 0 to 1	
Aroma:		Aroma:		Aroma:	
)(+ to 1	Toasted wheat	0 to 1+	Toasted wheat	)(to 1	Toasted--no wheat
0	Starchy	0	Starchy	0	Starchy
0	Raw, doughy	0	Raw, doughy	0	Raw, doughy
)(to)(+	FPC[b]	)(to 1+	FPC[b]	)(to 1+	FPC[b]
Amplitude of flavor:)(+ to 1		Amplitude of flavor: 0 to 1		Amplitude of flavor: 0 to 1	
Flavor:		Flavor:		Flavor:	
0 to)(	Sweet	0 to)(	Sweet	0 to)(	Sweet
)(to 1+	Toasted wheat	0 to 1	Toasted wheat	0 to)(	Toasted--no wheat
)(	Starchy	)(	Starchy	)(	Starchy
)(	Raw, doughy	0 to)(	Raw, doughy	0 to)(	Raw, doughy
)(to)(+	FPC[b]	)(to 2	FPC[b]	)(to 2	FPC[b]
Aftertaste:		Aftertaste:		Aftertaste:	
0 to)(	Wheaty	0	Wheaty	0	Wheaty
0 to)(	Sweet	0	Sweet	0	Sweet
0 to)(	FPC[b]	)(	FPC[b]	)(to 1	FPC[b]

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]See Table 8, Appendix.

Intensity key:
- 0 character note absent
-)(threshold
-)(+ between threshold and slight, closer to threshold
- 1 slight
- 1+ between slight and moderate, closer to slight
- 2 moderate.

Table 6. Composite flavor profiles of CSF[a]-supplemented chapatis.

5% CSF		10% CSF		15% CSF	
Amplitude of aroma: 1 to 2		Amplitude of aroma:)(+ to 1+		Amplitude of aroma: 0 to 1	
Aroma:		Aroma:		Aroma:	
)(to 1	Toasted wheat	)(+ to 1+	Toasted wheat	)(to 1	Toasted wheat
)(	Starchy	0	Starchy	0	Starchy
0 to)(	Raw, doughy	0 to)(	Raw, doughy	0	Raw, doughy
)(to 1	CSF[b]	0 to)(	CSF[b]	)(to 1+	CSF[b]
Amplitude of flavor:)(+ to 1		Amplitude of flavor: 0 to 1		Amplitude of flavor: 0 to 1	
Flavor:		Flavor:		Flavor:	
)(+ to 1+	Sweet	)(to 1	Sweet	)(to 1	Sweet
)(to 1	Toasted wheat	0 to 1	Toasted wheat	0 to 1	Toasted wheat
0 to)(	Starchy	0	Starchy	0 to)(	Starchy
0 to)(	Raw, doughy	0 to)(+	Raw, doughy	0 to 1	Raw, doughy
)(to 1	CSF[b]	0 to 1	CSF[b]	)(to 2	CSF[b]
Aftertaste:		Aftertaste:		Aftertaste:	
0	Wheaty	0	Wheaty	0	Wheaty
0 to)(	Sweet	0	Sweet	0	Sweet
0 to)(	CSF[b]	0 to)(	CSF[b]	)(to 2	CSF[b]

[a]Glandless cottonseed flour, Texas A & M University.

[b]See Table 8, Appendix.

Intensity key:
- 0 character note absent
-)(threshold
-)(+ between threshold and slight, closer to threshold
- 1 slight
- 1+ between slight and moderate, closer to slight
- 2 moderate.

Table 7. Composite flavor profiles of SPC[a]-supplemented chapatis.

5% SPC		10% SPC		15% SPC	
Amplitude of aroma:)(+ to 1+		Amplitude of aroma:)(+ to 1+		Amplitude of aroma:)(+ to 1+	
Aroma:		Aroma:		Aroma:	
1 to 1+	Toasted wheat	)(to 1	Toasted wheat	)(+ to 1	Toasted wheat
)(to 1	Starchy	)(to 1	Starchy	)(to 1	Starchy
0	Raw doughy	0 to)(	Raw doughy	0 to)(	Raw doughy
0 to)(	SPC[b]	0 to)(	SPC[b]	)(	SPC[b]
Amplitude of flavor:)(+ to 1+		Amplitude of flavor:)(+ to 1+		Amplitude of flavor:)(+ to 1+	
Flavor:		Flavor:		Flavor:	
)(to 1	Sweet	)(to 1	Sweet	)(to 1	Sweet
1	Toasted wheat	)(to 1	Toasted wheat	)(to 1	Toasted wheat
)(	Starchy	)(	Starchy	0 to 1	Starchy
0 to 1	Raw doughy	0 to)(+	Raw doughy	0 to)(	Raw doughy
0 to)(	SPC[b]	)(	SPC[b]	)(	SPC[b]
Aftertaste:		Aftertaste:		Aftertaste:	
)(	Wheaty	0 to)(	Wheaty	0 to)(	Wheaty
)(	Sweet	0 to)(	Sweet	0	Sweet
0	SPC[b]	0 to)(	SPC[b]	0 to)(	SPC[b]

[a]Fine Grind Swift's Food Protein, Swift Chemical Co.

[b]See Table 8, Appendix.

Intensity key:
- 0 character note absent
-)(threshold
-)(+ between threshold and slight, closer to threshold
- 1 slight
- 1+ between slight and moderate, closer to slight.

Table 8. Characteristics introduced by chapati supplementation.

With FPC[a]	With CSF[b]	With SPC[c]
	Aroma	
*Amine (fishy, clammy, anchovy)	*Crude resinous (paint-like, lactone-like, gassy, rubbery, sulfurous, medicinal, green, fir tree-like	*Legumy (green, beany)
*Alkaline (soapy)	Cardboardy	Resinous (cigar box, pepper aromatics)
*Oily (fish oil, fatty)	Nose burn	Alkaline
Cardboardy		Fatty
Nose burn		Cardboardy
Degraded protein (cooked protein, lactalbumin, cabbage-y)		
	Flavor	
*Amine (clammy, anchovy)	*Crude resinous (paint-like, lactone-like, gassy, rubbery, green, fir tree-like, oxidized)	*Legumy (green, beany)
*Alkaline (soapy, slick mouth-feel)	Gritty	*Alkaline (soapy, soda, lye-treated grain)
*Oily (fish oil, oxidized oil, sardine oil)	Tongue stimulation (bite, tingle)	Fatty (oxidized, fried chow mein noodles)
*Gritty	Soapy	Gritty
*Tongue stimulation (bite, burn)	*Bitter	*Tongue stimulation (bite)
Cardboardy	Drying	Cardboardy
Bitter	Buttery mouth-feel	*Bitter
		Drying
		Salivation
		Resinous

Table 8 (concl.).

With FPC[a]	With CSF[b]	With SPC[c]
	Aftertaste	
*Amine (fishy)	Crude resinous	*Legumy (green)
*Alkaline (soapy)	Soapy	*Alkaline (soapy, base identity, soapy mouth-feel)
*Oily (oxidized oil)	*Drying	Drying (mouth and tongue)
*Gritty	Lipolytic mouth-feel	
Tongue stimulation (bite, burn)	*Tongue stimulation (bite, rasp, tingle)	
Cardboardy		Cardboardy
Bitter	*Bitter	Bitter
Solvent-y		Resinous

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

*Major component, perceived by a majority of the panel members.

Table 9. Changes in the use properties of the control chapati flour introduced by increments in supplementation from 5-10-15%.

With FPC[a]	With CSF[b]	With SPC[c]
Appearance of the raw flours and doughs		
The 5 & 10% flours and doughs were darker than the control. The 15% flour was tan colored and the 15% dough was grayish in color.	Black specks were noticeable in all flours and doughs.	All were similar to the control.
Aroma during dough and chapati preparation		
FPC was definitely detectable in the 15% flour and in all the doughs but diminished during mixing and was present only on one occasion in the 15% dough during cooking.	CSF was detectable in all the flours and doughs but diminished during mixing and was present only on one occasion in the 15% dough during cooking.	SPC was detectable in the 10 and 15% flours and in all the doughs but diminished during mixing and was not noticeable in any of the doughs during rolling or cooking.
Mixing properties of the doughs		
All doughs were drier and stiffer than the control.	All doughs were drier and stiffer than the control.	The 5% dough was drier and stiffer than the control. The 10 & 15% flours would not form doughs until an additional 1 ml of water per 1 g of SPC was added.

Table 9 (concl.).

With FPC[a]	With CSF[b]	With SPC[c]
Handling properties of the doughs		
All doughs were less elastic than the control, and the 15% dough was difficult to roll.	All doughs were less elastic than the control but not difficult to roll. The 15% dough was sticky.	All doughs were less elastic than the control but not difficult to roll. The 15% dough had a sandy texture.
Cooking properties of the doughs		
The 10 and 15% chapatis browned very rapidly and did not puff fully.	All were similar to the control.	All chapatis browned more extensively than the control, and the 10% & 15% chapatis were dark and crisp on the outside.

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Table 10. Changes in the eating qualities of the control chapati introduced by increments in supplementation from 5-10-15%.

With FPC[a]	With CSF[b]	With SPC[c]
	Amplitude	
Decreased in the aroma and flavor.	Possibly increased at the 5% level, possibly decreased at the 10% level and definitely decreased at the 15% level in the aroma; decreased in the flavor.	Relatively unchanged--perhaps decreased in the aroma and flavor.
	Toasted wheat	
Decreased in the aroma and flavor; wheat absent in the aroma and flavor of the 15% sample.	Decreased, especially in the flavor.	Relatively unchanged--perhaps decreased in the aroma and flavor of the 10 and 15% samples.
	Starchy	
Decreased in the aroma only.	Decreased in the aroma and perhaps in the flavor.	Possibly increased in the aroma.
	Raw doughy	
Decreased in the aroma and perhaps in the flavor.	Decreased in the aroma and perhaps in the flavor.	Decreased in the aroma and perhaps in the flavor.
	Sweet	
Decreased.	Relatively unchanged--possibly increased in the 5% sample.	Unchanged.

Table 10 (concl.).

With FPC[a]	With CSF[b]	With SPC[c]
	Supplement character	
FPC detectable in the aroma and flavor of all samples.	CSF probably detectable in the aroma and flavor of all samples.	SPC fully detectable in both the aroma and flavor of the 15% sample only.
	Aftertaste	
Unchanged in 5% sample; in 10 & 15% samples, wheat and sweep absent and FPC present.	Wheat absent; sweet absent except perhaps in the 5% sample; CSF fully present in the 15% sample.	Wheat possibly decreased; sweet decreased in the 15% sample; SPC possibly detectable in the 10 & 15% samples.
	Other effects	
All chapatis darkened, gummy inside, poorly puffed, leathery, dry and gritty.	All chapatis darkened, gummy inside, less than fully puffed and contained black specks.	10 & 15% samples darkened and dry and crisp in spots.

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Table 11. Performance comparisons between each type of supplemented flour blend and the control.

	Pilot						Major								
	FPC[a]			CSF[b]			FPC[a]			CSF[b]			SPC[c]		
	5%	10%	15%	5%	10%	15%	5%	10%	15%	5%	10%	15%	5%	10%	15%
Raw flour															
Appearance	-	-	-	-	-	-	-	-	-	-	-	-	?	?	?
Aroma	?	?	-	?	-	-	?	?	-	?	-	-	?	?	-
Flavor	-	-	-	?	-	-	-	-	-	?	-	-	?	-	-
Dough															
Appearance	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+
Aroma-mixing	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Aroma-cooking	+	+	+	+	+	+	+	+	?	+	+	?	+	+	+
Mixing properties	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Handling properties	-	-	-	?	?	?	-	-	-	?	?	?	?	?	-
Cooking properties	-	-	-	+	+	+	+	-	-	+	+	+	?	-	-
Chapati															
Appearance	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-
Aroma	?	-	-	?	?	-	-	-	-	-	?	-	?	?	-
Flavor	?	-	-	?	?	-	-	-	-	-	?	-	?	-	-
Texture	-	-	-	+	+	+	-	-	-	-	-	-	+	-	-
Apparent digestibleness	+	+	+	-	-	-	+	+	+	+	+	+	+	+	+

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.
[b]Glandless cottonseed flour, Texas A & M University.
[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Key: + similar to the control
? may be slightly different from the control
- definitely different from the control.

Table 12. Flavor profile comparisons between each type of supplemented chapati and the control.

	FPC[a]			CSF[b]			SPC[c]		
	5%	10%	15%	5%	10%	15%	5%	10%	15%
Aroma:									
Amplitude	?	-	-	?	?	-	?	?	?
Toasted wheat	-	-	-	-	?	-	+	-	-
Starchy	-	-	-	+	-	-	?	?	?
Raw doughy	-	-	-	-	-	-	-	-	-
FPC character	-	-	-						
CSF character				-	?	-			
SPC character							?	?	-
Flavor:									
Amplitude	-	-	-	-	-	-	?	?	?
Sweet	-	-	-	-	+	+	+	+	+
Toasted wheat	-	-	-	-	-	-	+	-	-
Starchy	+	+	+	?	-	?	+	+	?
Raw doughy	+	?	?	?	?	?	?	?	?
FPC character	-	-	-						
CSF character				-	?	-			
SPC character							?	-	-
Aftertaste:									
Wheat	?	-	-	-	-	-	+	?	?
Sweet	?	-	-	?	-	-	+	?	-
FPC character	?	-	-						
CSF character				?	?	-			
SPC character								?	?

[a]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[b]Glandless cottonseed flour, Texas A & M University.

[c]Fine Grind Swift's Food Protein, Swift Chemical Co.

Key: + similar to the control
? may be slightly different from the control
- definitely different from the control.

Table 13. Essential amino acid compositions of test flours and supplements.[ab]

	Iso-leucine	Leucine	Lysine	Methio-nine	Phenyl-alanine	Threo-nine	Valine
Provisional pattern	270	306	270	144	180	180	270
97% extraction Gaines Wheat Flour	201 (74.4%)	414 (135.3%)	196 (72.6%)	100 (69.4%)	243 (135.0%)	191 (106.1%)	304 (112.6%)
FPC[c]	281 (104.1%)	530 (173.2%)	533 (197.4%)	170 (118.1%)	263 (146.1%)	299 (166.1%)	354 (131.1%)
5% FPC	215 (79.6%)	427 (139.5%)	284 (105.2%)	115 (79.9%)	236 (131.1%)	212 (117.8%)	296 (109.6%)
10% FPC	231 (85.6%)	454 (148.4%)	346 (128.1%)	129 (89.6%)	244 (135.6%)	235 (130.6%)	304 (112.6%)
15% FPC	230 (85.2%)	446 (145.8%)	366 (135.6%)	131 (91.0%)	235 (130.6%)	236 (131.1%)	293 (108.5%)
CSF[d]	170 (63.0%)	348 (113.7%)	250 (92.6%)	90 (62.5%)	318 (176.7%)	192 (106.7%)	255 (94.4%)
5% CSF	187 (69.3%)	382 (124.8%)	201 (74.4%)	93 (64.6%)	251 (139.4%)	184 (102.2%)	281 (104.1%)
10% CSF	184 (68.1%)	378 (123.5%)	213 (78.9%)	93 (64.6%)	268 (148.9%)	187 (103.9%)	277 (102.6%)
15% CSF	182 (67.4%)	372 (121.6%)	220 (81.5%)	93 (64.6%)	277 (153.9%)	188 (104.4%)	273 (101.1%)

Table 13 (concl.).

	Iso-leucine	Leucine	Lysine	Methio-nine	Phenyl-alanine	Threo-nine	Valine
SPC[e]	284 (105.2%)	533 (174.2%)	392 (145.2%)	88 (61.1%)	324 (180.0%)	252 (140.0%)	308 (114.1%)
5% SPC	214 (79.3%)	427 (139.5%)	238 (88.1%)	92 (63.9%)	254 (141.1%)	199 (110.6%)	293 (108.5%)
10% SPC	225 (83.3%)	441 (144.1%)	266 (98.5%)	90 (62.5%)	264 (146.7%)	206 (114.4%)	289 (107.0%)
15% SPC	240 (88.9%)	467 (152.6%)	296 (109.6%)	91 (63.2%)	280 (155.6%)	219 (121.7%)	298 (110.4%)

[a]Expressed as mg of amino acid per g nitrogen, and % of provisional pattern.

[b]Tryptophan destroyed during analysis.

[c]Food Grade Type I Marine Protein Concentrate, Alpine Marine Protein Industries, Inc.

[d]Glandless cottonseed flour, Texas A & M University.

[e]Fine Grind Swift's Protein, Swift Chemical Co.

PERFORMANCE OF PROTEIN SUPPLEMENTED FLOURS FOR CHAPATIS

by

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B. S., University of Omaha, 1968

AN ABSTRACT OF A MASTER'S THESIS

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Nine protein-supplemented flours were evaluated for their performance in the preparation of chapati, an unleavened bread consumed in West Pakistan. A commercially available fish protein concentrate (FPC), a pilot plant sample of cottonseed flour (CSF) and a commercially available soy protein concentrate (SPC) each were used to replace Gaines wheat flour at the 5, 10 and 15% levels by weight. Performance evaluations were based on the use properties of the flour blends and the eating qualities of the supplemented chapatis in comparison to those of the unsupplemented flour and control chapati, respectively. "Standardized" procedures were developed for the preparation and examination of all samples. The flours and cooked chapatis were analyzed by the flavor profile method. Predictions for potential acceptability of the flour blends by the native consumer were based on performance differences between the blends and the unsupplemented control flour.

FPC supplementation at all levels imparted atypical and probably undesirable use properties and eating qualities to the flour blends and the supplemented chapatis, respectively. It was concluded that the 10 and 15% FPC-supplemented chapati flours and probably the 5% blend as well would be unacceptable to the native consumer.

Undesirable appearance factors seemed to contraindicate the use of the particular CSF studied as a chapati supplement. CSF-supplemented flours, doughs and chapatis all contained noticeable black specks, the connotation of which would be apt to adversely affect the acceptability of all flour blends.

Furthermore, belching, which implies indigestion, sometimes resulted from the tasting of chapatis prepared from flours containing CSF supplementations.

Based upon both use properties and eating qualities, it was concluded that the 15% SPC-supplemented flour would be unacceptable to the West Pakistani consumer. The 10% flour blend would be apt to be unacceptable unless water absorption could be effectively adjusted by the consumer and atypical chapati color and flavor would not be objectionable. SPC supplementation at the 5% level appeared not to adversely affect the potential acceptability of the flour blend.