EFFECTS OF VARYING PROPORTIONS OF WHEAT PROTEIN CONCENTRATE ON THE QUALITY OF CHAPATIS

by

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TABLE OF CONTENTS

INTRODUCTION

At the present time more than half of the population in the less-developed areas of the world is suffering from hunger or inadequate nutrition in one form or another according to Fischnich (1966). Schaefer (1963) reported that in practically every developing country, over half the population dies before reaching the age of 15 and in many areas half or more of the infants die before reaching 5 years. This is a direct result of a combination of inadequate nutrition and widespread infectious disease. Malnutrition also takes a huge toll in those who survive in incapacity, inefficiency, lowered production, loss of energy, and susceptibility to disease.

The largest problem facing the newly developing countries according to Parpia (1968) is food shortage, both qualitative and quantitative. These countries have 71.3% of the world's population, 42.7% of the food produced, and barely 21.5% of the income. An estimated 30-50% of the food produced is lost also. The average person eats barely 70-80% of the optimum supply of calories and 60-80% of the recommended protein intake.

One of the world's most widespread nutritional deficiencies today is that of high-quality protein. The lack of protein is not common in the United States, but it prevails in the underdeveloped and developing countries. Many of the people in these countries subsist on cereal grain that often contains protein adequate in amount but of low quality (Food and Agriculture Organization, 1963). Sullivan (1967) stated that grains supply over 50% of all human energy in the world and, in many countries, now provide nearly 70% of the total food intake. Therefore, the improvement of cereal grains has become of considerable importance.

World food needs and supplies for the future invariably stress increasing dependence upon food grains. In India, rice, wheat and the millets are the main food grains or cereals consumed. They are the cheapest source of calories in the diet and may contribute as much as 70-80% of the calories of the poor classes according to Aykroyd et al. (1966). India has both an inadequate supply of nourishing foods and an inadequate knowledge of wise food selection (Pasricha, 1964). Food prejudices and taboos are also present. Simoons (1966) reported that food prejudices and taboos are of great importance when consumer acceptance is affected. Food habits are difficult to change and make it hard to introduce new products. Therefore, if a staple food as chapatis could be supplemented in an acceptable manner, the problem of introducing a new product would be eliminated.

Senti et al. (1967) stated that food aid programs in order to be successful must disturb the normal situation in a given locality or nation as little as possible. Schaefer (1963) indicated that cheap, easily distributed and, most of all, acceptable supplemental foods are needed in a food aid program.

The chapati was chosen for the present study since it is a common Indian food somewhat equivalent to our bread. Sinha (1964) indicated that approximately 80% of the wheat consumed in

India is in the form of chapatis. Chapatis are eaten mainly by the people in the northern parts of India and to a lesser extent in other parts of the country as noted by Shyamala and Kennedy (1962) and is a staple eaten at practically all meals which makes it important as a source of protein. The chapati is made from a whole wheat flour and water dough, without fermenting. It is shaped in the form of a disk about 6-8 inches in diameter and 2-3 mm thick, and cooked on a hot plate heated by the fuel supply available.

The purpose of the present study was twofold: 1) to determine whether or not wheat protein concentrate could be substituted satisfactorily for part of the whole wheat flour in Indian chapatis, and 2) to compare the quality of a control product containing 100% whole wheat flour with that of chapatis using 3 different levels of wheat protein concentrate to replace equal weights of whole wheat flour.

REVIEW OF LITERATURE

Food Production and Supply in India

Gopalan (1962) indicated that the picture of food production was hopeful when figures for the national nutritional requirements were compared with the estimated national availability of foodstuffs. Parpia (1968) commented that higher milling outputs could add between 2 and 3% to the food grain supplies.

Parpia (1968) remarked that India could achieve self-sufficiency if food losses, i.e., those occurring in the field, during storage, processing and distribution, due to rodents, insects and microorganisms, could be cut in half. He recommended proper application of technology to existing conditions as a means of solving not only the problem of food shortage but also that of economic growth. He further stated barely 30% of the food produced in India is sold for consumption in urban areas. This food along with the imported food is stored in warehouses, which may in some cases help control losses. However, in rural areas the means of storage are often inadequate, and farmers are urged to store their produce in cooperative warehouses. The storage losses of food grains were estimated at 15% of the total production.

Currently there are several programs for increasing food production and supply. Still the cultural, social, economic and physical factors condition the availability and intake of different foodstuffs in various regions of the country and among diversified segments of the population.

Malnutrition

Malnutrition in India. In 1962, Gopalan noted that the problem of malnutrition is far from being solved as it is interwoven with a variety of social and economic factors and cannot be considered as only a public health problem. This statement could also be made about many of the other developing countries.

According to Schaefer (1963) the normal appearance of the "people in the street" in developing countries may be misleading as an indication of the true nutritional status of the population. The weak and severely malnourished are not seen walking in the streets. When there is severe malnutrition, undoubtedly there is also a short life expectancy and a high mortality rate for children. Scrimshaw (1962) stated that development of serious malnutrition as a result of defective feeding of the weaned infant is a common problem in almost every underdeveloped country and territory in the world. In fact in the underdeveloped areas there is a close relationship between malnutrition and high mortality among infants and young children due to infections. Gopalan (1962) implied the widespread protein malnutrition in India is partly responsible for the high mortality of children under 5 years.

Factors Contributing to Malnutrition. There are several major factors contributing to malnutrition. The population problem is first in India according to Gopalan (1962). In 1961 the census of India listed a population of 438 million, with the rate of growth from 1961 to 1970 estimated at 1.4%. Other developing countries also are concerned with an increase of population. Industrialization which involves shifting people from rural to urban areas has its effect in that living conditions, dietary habits, and sense of values are changed. Shyamala and Kennedy (1962), as well as Gopalan (1962), suggested social and cultural factors have a great influence on dietary habits. Many of the faulty feeding habits arise from ignorance, prejudice, and superstition. Therefore, programs in nutrition education were stressed by the Food and Agriculture Organization (1963) and Gopalan (1962). The latter also signified that nutrition education should be integrated with general, social and economic, uplift programs including environmental sanitation if the programs are to be successful.

Simoons (1966) observed that dietary habits are influenced by food prejudices. As examples of these he cited some religions and how they affect diets. The Buddhists are reluctant to take life so avoid eating fish. They prefer to kill larger animals that will feed more people thus limiting the number to be killed. The Jain sect shows extreme expression of vegetarianism. They have such a love of life that they go to extreme lengths to avoid even the killing of insects; and all meat, fish and eggs are forbidden them. The Hindus are also strongly dedicated to vegetarian belief and eat neither eggs, meat, nor fish as they regard all life as sacred. Certain religious taboos limit protein consumption to cereals and vegetables according to Shyamala and Kennedy (1962) and Simoons (1966).

Protein Malnutrition. Protein malnutrition in children, which in the classical severe form is known as kwashiorkor, is often found in certain parts of India (Gopalan, 1962 and Reddy, 1968). Kwashiorkor, as described by Schaefer (1963), is characterized by subnormal weight, mental apathy, edema, muscular wasting, changes in the texture and pigmentation of the hair and skin, fatty liver, anemia, and diarrhea, and is often associated with other infections and severe vitamin A deficiency resulting in permanent blindness. Retarded growth and maturation are clinically observable evidence of the occurrence of protein malnutrition in the general child population. Marasmus which results from semi-starvation is an even broader and more prevalent gross malnutrition. Scrimshaw (1962) observed that problems start to develop when supplementary feeding of the infant becomes necessary, and the real crisis in technically underdeveloped regions comes with weaning of the infant.

Parpia (1968) mentioned that the low per capita income in India of $48 per year was insufficient and one reason that 80% of the Indian diet was composed of cereals and legumes. He indicated this as part of the reason for protein malnutrition.

Protein

Importance of Protein. Protein is the basis of living tissue and is essential in the maintenance and repair of the body. The secondary function of protein is growth (Chaney, 1960 and Robinson, 1968). Proteins, being one of the chief substances in the cells of the body, form the important constituents of muscles and other tissues and vital fluids like blood (Aykroyd et al., 1966). Chaney (1960), Aykroyd et al. (1966), Kleiner and Orten (1966), and Robinson (1968) all observed that enzymes and antibodies are mainly protein in nature.

Amino acids are the units from which the complex protein structure is built. Eight of the 22 amino acids are essential for growth and are required for maintenance of health in adults as well as in children. The essential amino acids must be ingested since they cannot be synthesized (Kleiner and Orten, 1966).

Nutritive Value of Protein. Aykroyd *et al*. (1966) remarked that the nutritive value of protein is dependent on the digestibility and essential amino acid make-up. Narasinga Rao (1968) pointed out that the nutritive value of protein varies with the type of food consumed, as animal proteins supply amino acids in better proportions than the vegetable foods. He also mentioned that age and physiological condition must be considered when determining protein requirements.

Proteins of vegetable origin predominate in a typical Indian diet and are only about 60-70% as nutritious as egg proteins which have the right proportion of amino acids according to Narasinga Rao (1968). Therefore, larger amounts of vegetable proteins than animal are needed to meet protein requirements. The diet also must be well-balanced in other nutrients in order for the body to make the most efficient use of protein. Adequate calories should be available to prevent utilization of protein for energy.

Protein Supply and Requirements. Parpia (1968) reported that in India the average protein supply per capita was 50 g per day. The higher income groups consumed larger amounts of vegetable and animal proteins than the lower income groups who may get only 35 g or less protein a day. The animal protein fraction consumed by low income groups may be less than the national average consumption of 6 g a day.

Narasinga Rao (1968) listed the protein requirements for the people of India (Table 1). These allowances apply for a majority of the population and allow sufficient margin for increases in the protein requirement of an individual such as those due to emotional disturbance, infection and the like. He stressed that these figures (Table 1) are correct for normal people in good health, but denoted many people possess poor body stores of protein. Thus higher intakes of protein than that indicated,

Table 1. Daily protein requirement of different groups of population (Narasinga Rao, 1968).

Age group years	Requirements per kg of body weight (in terms of a good protein like egg)		Average body weight kg		Total protein needs[a] grams/day/person (in terms of the usual dietary proteins)	
	Male	Female	Male	Female	Male	Female
Children						
0-1	1.70	1.70	6.0	6.0	13	13
1-3	0.90	0.90	10.0	10.0	15	15
4-6	0.83	0.83	15.0	15.0	21	21
7-9	0.79	0.79	19.5	19.5	26	26
10-12	0.74	0.74	25.0	25.6	31	32
13-15	0.72	0.70	35.0	36.0	42	42
16-19	0.66	0.64	46.0	42.0	51	45
Adults	0.60	0.60	55.0	45.0	55	45
Pregnant women						55
Nursing women						70

[a]The total protein needs are given in terms of the predominately mixed vegetable proteins which are about 60 per cent as effective as good quality animal proteins.

especially for pregnant women and nursing mothers, would certainly be advantageous.

Wheat

Production of Wheat. Kent-Jones and Amos (1957) stressed that wheat was an important cereal because it could be grown in a variety of soils and climates. The production of wheat is related to water supply, intensity of cultivation and type of wheat sown; and the principal producers are the United States, U.S.S.R., Europe, Canada, India and Pakistan. The total world production of wheat in 1966 was 10.10 billion bu (United States Department of Agriculture, 1967).

Although India has a majority of people who eat rice (Senti et al., 1967), it is also an important wheat growing country with an annual estimated production of 11.8 million tons for 1963 (Bains and Irvine, 1965). However, in 1968 Parpia noted India's wheat production was about 11 million tons.

Today India imports wheat from other countries. Sullivan (1967) commented that in 1966, India imported ¼ of the wheat crops of the United States; and Parpia (1968) stated that India imported between 6 and 8 million tons of wheat.

Types of Wheat. Wheat can be classified as hard or strong and soft or weak. The hard or strong wheat flours are rich in protein and require a large amount of water to make a dough of proper consistency and handling qualities. The soft or weak flours have relatively low protein content and form a soft, relatively nonelastic gluten and have low water absorbing capacity and inferior handling qualities (Griswold, 1962 and Ahmad, 1960). Griswold (1962) further noted that flour made from hard wheat is used ordinarily for making bread and that from soft wheat is best suited for various types of cakes, pastry, and crackers. Bains and Irvine (1965) reported that Indian wheats have certain distinctive features in that they give high yields of straight grade flours, but yield doughs which are tight and short.

Wheat sometimes is classified as winter or spring wheat. Griswold (1962) specified that winter wheat is planted in the fall in moderate climates, is harvested in early summer and usually gives higher yields than the spring wheat. Spring wheat is planted in the spring and harvested in late summer.

Composition of Wheat. Wheat is composed of carbohydrates (mainly starch), proteins, minerals and vitamins and is regarded mainly as a source of energy (Waggle et al., 1967). Griswold (1962) stated that calcium and iron are probably the most important minerals in wheat. Wheat is an excellent source of all B-vitamins but has been regarded chiefly as a major dietary source of thiamine and niacin (Bradley, 1965 and Mast, 1964).

Bradley (1965) stated that wheat is an incomplete protein, with lysine being the most limiting amino acid. Nevertheless, Sinha (1964) indicated that wheat proteins are important and contain 2 principal components known as glutenin and gliadin, which on hydration unite to form gluten. This gluten forming capacity enables wheat to form a coherent, elastic, tough, ductile, tenacious and pliable dough which can extend and contract on stretching and relaxation more or less like rubber. It is this characteristic which has given wheat its unique place among food grains.

The nutritive content of wheat may vary depending on the variety, environment, fertilizer and treatment. Kent-Jones and Amos (1957) reviewed various publications regarding the composition of a variety of wheats and compiled a range of values given in Table 2.

Table 2. Proximate composition of wheat (Kent-Jones and Amos, 1957).

Factor	%
Moisture	9.0-18.0
Protein (N x 5.7)	8.0-15.0
Cellulose (fiber)	2.0- 2.5
Fat	1.5- 2.0
Mineral matter	1.5- 2.0
Carbohydrate	62.0-71.0

Milling of Wheat. Griswold (1962) explained that the purpose of the milling process is to separate the endosperm from the bran and germ that surround it. This separation is possible because endosperm is more easily crushed than bran and germ. The wheat seed consists of the germ or embryo, the endosperm that is a temporary food supply for the young plant, and the bran which encloses the endosperm.

The milling process can be separated into 2 stages:

cleaning and tempering of the wheat, and separating of the endosperm from the bran and germ (Griswold, 1962). It is during the second stage according to Meyer (1961) that corrugated rollers lightly grind the tempered wheat in successive breaks yielding very fine particles (flour), intermediate particles (middlings) and coarse particles (chop or stock). At the second break, the chop (pieces of endosperm and bran) is broken down principally to yield bran. The middlings contain endosperm, bran and the germ. Some of the bran is removed and the middlings are gradually reduced to finer particles. After each reduction, sifters separate the flour, middlings and chop until most of the endosperm has been removed as flour. The remaining fine middlings, bran, and a little germ are known as millfeeds and are usually for animals.

Millfeeds and Wheat Protein Concentrate

The most efficient and economical use of wheat, a staple cereal in many parts of the world, is of vital concern to all countries. The millfeeds from which wheat protein concentrate is derived represent around 25% of the wheat milling tonnage and are composed of bran and shorts which are the parts that remain after the straight flour is removed (Johnston, 1965).

Today millfeeds are used principally for animal feeding, but recently several investigators have given their attention to millfeeds as a potential human food. Fellers et al. (1966) found that a wheat protein concentrate could be made by the dry milling of millfeeds yielding flours high in protein, low in fiber and suitable for use in food products. Coarse bran, fine bran, and shorts were milled at various moisture levels (3-17%). Flour yields were highest from the shorts and lowest from the coarse bran. The flour fractions were slightly higher in total sugars and fat, considerably higher in protein and starch, but lower in fiber, pentosan and ash than the millfeeds. Farrell et al. (1967) reported similar results.

Complete information about millfeeds is lacking. Mennell (1963) recommended that millfeeds be considered as a product rather than a by-product of wheat. In 1965 Johnston reviewed millfeeds and commented on their possible future. He believed that the real potential of millfeeds had been overlooked. The Millfeed Research Committee appointed by the Millers' National Federation in 1963 was still active in developing sound information on millfeeds that should lead to a brighter future for them.

Investigations regarding millfeeds by Waggle et al. (1967), Farrell et al. (1967), and Sullivan (1967) were supported by the Millers' National Federation. Sullivan (1967) reviewed nutritive value and economics of wheat-based products for world use and observed that wheat concentrate offers particular promise because of its high nutritional value and low cost. She reported that blends of 70% straight grade, hard winter wheat flour and 30% wheat concentrate from shorts used in Egyptian bread were evaluated in Cairo, Egypt. Identical blends were used in chapatis, biscuits and other products made in India and Pakistan. The blends were found to be nutritionally superior to the local wheat flour.

Bradley (1965) noted that millfeeds had been shown to contain good quality protein. Waggle et al. (1967) stated that the milling operation concentrates essential amino acids in millfeeds. Thus on the basis of amino acid content, mill products have higher nutritional value than the flour or wheat from which they are milled.

Chapatis

Nutritive Value of Chapatis. The chapati is a basic, staple and widely accepted food item in India and Pakistan, but the nutritive value is rather low. The protein value of chapatis was determined by Shyamala and Kennedy (1962). Heating the flour used in chapatis increased the protein efficiency ratio (P.E.R.) 20% over that for unheated flour. Replacing 10% of the whole wheat flour with defatted soybean flour or nonfat dry milk further increased the P.E.R. Chaudhry (1968) stated that chapatis are inadequate in iron, calcium, thiamine, niacin, riboflavin, and vitamins A and D. Furthermore, he indicated that the chapati is often the only source of food energy and the major source of all essential nutrients; however, the protein found therein is incomplete. When one realizes that the chapati makes up a large proportion of the diet of many East Asian people, the importance of inadequate nutrients is emphasized.

The possibility of supplementing chapatis has been considered as a partial solution to the problem of malnutrition in India and Pakistan. This program of supplementation would be equivalent to the enrichment of staple cereal products in the United States and other Western nations. Imtiaz (1962) prepared a mix of 75% whole wheat flour, 15% medium fat soybean flour and 10% dry skim milk. She noted that this mix had good storage ability and recommended that it be introduced to Pakistan as a prepared chapati mix. Murty and Austin (1963b) made blends of flours using jowar (Sorghum vulgare), bajra (Pennisetum typhoides), Bengalgram (Cicer arietinum) and tapioca (Manihot utilissima). Each flour was blended with wheat flour in the following percentages: 5, 10, 15, 20, 30, 40 and 50. They found that wheat flour could be mixed with 15-20% of tapioca or other non-wheat flours without adversely affecting its chapati-making qualities. Bengalgram flour was the exception as it gave a prominent gram flavor to the chapati even at a lower percentage. Chaudhry (1968) supplemented the chapati with synthetic nutrients. He observed that when the problem was general malnutrition, and not specifically protein, that a 0.2 or 0.4% level lysine supplementation might do more harm than good.

Method of Preparation of Chapatis. The chapati has been known for centuries and there has been little change in the method of preparation. In making the dough, whole wheat flour (atta) and water are used, and sometimes salt and/or fat added. The dough thus formed is slacker than bread dough, but the recorded dough characteristics seem to depend on the sense of touch of the operator. One experienced in the making of chapatis can tell the quality of the chapati by the feel of the dough (Ahmad, 1960).

As wheat in India, Pakistan, and many other countries of this region is mainly consumed in the form of chapatis, the type of wheat suited for this purpose is discussed. Aziz and Bhatti (1962) stated that the wheat should be light colored bold grains, with fairly high protein content but not too strong gluten. The water absorption of the flour should be high and the dough should not desiccate too much while being baked.

Several problems concerning the preparation and evaluation of chapatis have been encountered in that no standard formula for the preparation is available even in research laboratories, and no objective methods for evaluating the quality of cooked chapatis have been reported (Aziz and Bhatti, 1962 and Chaudhry, 1968). Sinha (1964) mentioned that no systematic and scientific study had been made either of the ingredients which contribute to the preparation of an ideal chapati or of the method of preparation. Most likely there cannot be universal agreement in this regard, but in general, the characteristics of chapatis would be common and acceptable to the majority of consumers. For the most part completed studies have been dependent upon subjective evaluations.

Water Absorption of Flour. The water absorption of flour varies with the type of flour used. Murty and Austin (1963a) said that if absorption is high, the dough handles better and the products have better shape and texture than when the absorption is low. Nath et al. (1957) used 3 parts of flour with each 2 parts of water by weight, and Shyamala and Kennedy (1962) 1 part of whole wheat flour with 3 parts of water by volume. For each 100 parts of wheat flour Kameswara Rao et al. (1964) used an average of 60-70 parts of water. Sinha (1964) found with 50 g of atta that approximately 45 cc of water were required to prepare a dough, but also pointed out that the exact quantity varied for different varieties of wheat and quality of atta. Kameswara Rao et al. (1966) combined a kilo of wheat flour with 625 to 650 ml of water, whereas Chaudhry (1968) incorporated 70-73% water.

Preparation of Dough. Ahmad (1960) stated that dough is mixed to hydrate the starch and proteins and to incorporate uniformly any other ingredient as salt, fat, etc. Aziz and Bhatti (1962) prepared their dough in a Hobart mechanical mixer using medium speed for 5 min, although the majority of the studies reviewed used a method of hand mixing and kneading.

Resting of Dough. Aziz and Bhatti (1962) suggested these possible reasons for the resting of the dough: 1) to provide conditions for maximum hydration of the several constituents of atta (starch, protein, etc.), thus allowing for optimum development of the dough, and 2) to stimulate enzymatic activity for breaking down the starch-protein complex into simpler aggregates. They allowed the dough to rest 1 hr in a proofing cabinet at 86°F with 80% relative humidity. Nath et al. (1957), Murty and Austin (1963a), and Kameswara Rao et al. (1964) permitted the dough to rest for 30 min. Imtiaz (1962) had a 25 min rest for the dough.

Sinha (1964) allowed a 45 min rest for all varieties of wheat dough tested except the Durum wheat doughs which rested 1 hr. Yaisn et al. (1965) held the dough for 1 hr at 30°C.

Weight, Size, Cooking Time and Temperature for Chapatis. The weight and size of chapatis as reported in the literature varies. The cooking time reported varied with the temperature of the griddle or plate and with the weight, size and thickness of the chapati. Nath et al. (1957) rolled a 55 g dough ball to a 5-inch diameter and 2 mm thickness. Aziz and Bhatti (1962) used 100 g of dough with no reported diameter, Murty and Austin (1963a) 25 g flour to make a dough with a 15 cm diameter, whereas Sinha (1964) used a 47.5 g portion rolled to a 15 cm diameter. Shyamala and Kennedy (1962) also gave no weight for the dough ball but stated the size as 5 inches in diameter and 1/8 to 1/4 inch thick. They cooked the chapati on a hot ungreased griddle for approximately 1½ min on each side. Kameswara Rao et al. (1966) cooked a 45 g dough ball of 7 inch diameter on a plate, heated to 220-240°C (428-464°F), for 2 min with 1 additional min for puffing. Chaudhry (1968) using a 50 g dough ball of 6-7 inch diameter used a hot plate 290-300°C (554-572°F) which took 2 min to cook and puff each chapati. The other studies reviewed were vague about exact cooking times and temperatures.

Characteristics and Evaluation of Chapatis. According to Ahmad (1960) a good chapati is of uniform thickness, is soft and smooth and easily chewed, does not get dry and hard when left for some time, and its peripheral edge maintains the same texture and consistency. Aziz and Bhatti (1962) indicated that a high quality chapati should be: 1) white to creamy in color, 2) very soft and silky to touch, 3) easy to chew and sweetish to taste, 4) flexible without completely breaking on rolling in the hand, and 5) should not stale or become hard and unpalatable readily. Sinha (1964) noted the chapati to be: 1) creamy-yellow to white in color with relatively more of the white shade and neither red, brown, nor yellow, 2) not leathery or tough or too brittle, gritty or sticky, 3) not too dry or too soft and sticky, even if eaten some hours after its preparation, 4) sweetish to taste, 5) well puffed on both sides so that the inner layer is well baked and has desirable texture, and 6) to have a slight caramel flavor and a few stray dark spots.

In evaluating chapatis Murty and Austin (1963a) indicated that: 1) the water requirement should be high for preparing the dough, 2) puffing should be rapid and full, 3) the surface or crust should be uniform and creamy white, 4) texture should be soft, smooth and pliable, and 5) taste should be sweetish.

Yaisn et al. (1965) studied the preservation of chapatis. The appearance and smell, texture, and taste were evaluated as indications of quality.

PROCEDURE

Ingredients and Method Used

A chapati recipe from Mrs. Balbir Singh's Indian Cookery (1961) was used in slightly modified form. A 100% whole wheat flour from Inland Mills, Inc., Des Moines, Iowa, and tap water were the major ingredients. "WHEAPRO", approximately a 20% wheat protein concentrate obtained from shorts, from a mixture of hard red winter wheat varieties supplied by the Dixie Portland Flour Mills, Inc., Arkansas City, Kansas, was used as the variable. See Table 3 for the analysis of the whole wheat flour and the wheat protein concentrate. All ingredients were obtained at one time from one source and the same equipment was used throughout the study.

Table 3. Proximate analyses of experimental foodstuffs.

Factor	Wheat[a] %	Wheat protein concentrate[b] %
Protein (N x 6.25)	15.00	22.13
Moisture	11.25	7.01
Ash	1.60	5.74
Carbohydrates	68.15	58.96

[a]Analysed by Inland Mills, Inc., 1925 East Grand Avenue, Des Moines, Iowa.

[b]Analysed by chemical laboratories, Kansas State University, Manhattan, Kansas.

The control product (A) was made by sifting 230 g whole wheat flour and 3 g salt into a $1\frac{1}{2}$ qt mixing bowl. The flour and salt were put through a coarse sieve to distribute the ingredients as uniformly as possible. A depression was made in the center of the heap thus formed and 150 ml tap water poured into it, then it was mixed for 45 sec into a soft dough. The three variables were made by substituting 10, 20 and 50% of the whole wheat flour used in the control recipe for equal weights of WHEAPRO. For treatment (B) 23 g WHEAPRO was added to 207 g whole wheat flour; treatment (C), 46 g WHEAPRO to 184 g whole wheat flour; and treatment (D), 115 g WHEAPRO to 115 g whole wheat flour. In each treatment the WHEAPRO was added to the whole wheat flour and salt before sieving.

Each dough was kneaded for 15 min. After the first 3 min, while alternately pressing and folding the dough, water was added gradually every 30 sec until 15 ml had been added. The kneaded dough was placed in the mixing bowl and sprinkled with 10 ml water; covered with a damp cloth and left to rest for 30 min. The dough was kneaded again for 3 min. (Good results can be obtained only if the dough is kneaded sufficiently and properly.)

Each dough was divided into 30 g pieces and shaped into round spheres (Fig. 1). Each sphere was rolled in $1\frac{1}{2}$ g whole wheat flour and flattened by placing it on the left palm and pressing it with the fingers of the right hand. The flattened sphere was placed on a board with the remaining flour; then the dough was rolled with a rolling pin into a thin circular chapati disk 6 inches in diameter (Fig. 2). The rolled chapati was transferred quickly onto an aluminum griddle preheated to 450°F; turned after 30 sec and pressed with a soft cloth in order to spread the steam uniformly between the layers (Fig. 3). In 35 sec it was turned for the second time and removed from the heat 25 sec later

Fig. 1. Chapati dough rolled to 6-inch diameter with weighed portion of dough and flour on tray in foreground.

Fig. 2. Rolling chapati dough to a diameter of 6 inches.

Fig. 3. Chapati being pressed with a soft cloth while cooking on aluminum griddle over thermostatically controlled gas burners.

making the total cooking time $1\frac{1}{2}$ min. Immediately after removing from the heat, the chapati was oiled, $\frac{1}{2}$ g per side, and placed in a napkin-lined covered casserole until evaluated.

Evaluation

The following measurements were made to evaluate the chapatis:

Cooking Loss. The unoiled samples were weighed before and after cooking to determine any cooking loss.

Percentage Total Moisture. The percentage total moisture was determined in the C. W. Brabender semi-automatic rapid moisture tester. Two unoiled chapatis were torn approximately into eighths and blended in a one speed Waring Blendor for 30 sec. Duplicate 10 g aliquots, placed in Teflonized pans, were dried for 80 min at 170°C and readings recorded.

Color. A Gardner Automatic Color Difference Meter--Model AC-2A Series 200 was used for the color determination. A standardized tile as similar in color to the chapati as possible (Rd = 15.53, a = +9.33, b = +13.10) was used to standardize the instrument. Rd (reflectance), a+ (redness) and b+ (yellowness) values were determined on duplicate samples cut from the center of oiled chapatis to fit the color cell. Three readings were taken on each sample; between readings the sample was turned through a 120° angle. The color value for each sample was considered to be the average of these 3 readings. To determine the degree of redness for each sample, a/b was calculated.

pH. The pH of the dough was determined on a Beckman Model 76 Expanded Scale pH Meter. A buffer with a pH of 6.86 was used to standardize the pH meter. The dough was soaked in 100 ml distilled water for at least 45 min. Then the dough and water were placed in a one speed Waring Blendor and blended for 1 min. The slurry was transferred to a 150 ml beaker and the pH reading taken at 26°C.

Volume. Volume of each chapati was determined by rape seed displacement. The volume of a shallow pan was determined first by pouring the seed into it until overflowing and then leveling the seed by passing a straight edge across the top of the pan. The volume of seed in the pan then was measured in a graduated cylinder. To measure the volume of a chapati, the sample was placed in the shallow pan and the seed poured over it until the pan was overflowing. The seed was then leveled and the volume measured as before. The amount of displaced seed represented the volume of the chapati.

Palatability. The palatability evaluations were made in the organoleptic laboratory by a panel composed of 3 students from India, who were familiar with the chapati, and 6 other graduate students and faculty who were available to taste regularly (Fig. 4). A whole chapati was used for judging external characteristics of appearance and color under the Macbeth Skylight (Fig. 5). Each panel member received one-third of a chapati as a sample to be scored (Form 1, Appendix) for tenderness, moisture content, texture and flavor.

Fig. 4. Taste panel in the process of evaluating chapatis.

Fig. 5. Chapatis as presented to the taste panel for evaluation of appearance and color characteristics.

1 = 0% WHEAPRO   3 = 20% WHEAPRO

2 = 10% WHEAPRO   4 = 50% WHEAPRO

Experimental Design and Analyses of Data

A randomized balanced incomplete block design with 3 replications of each treatment was used for preparing and evaluating the chapatis. There were 4 treatments with 3 treatments being prepared each period for a total of 16 (Form 2, Appendix). Data for each measurement used to evaluate the palatability of chapatis were subjected to the following analysis of variance:

Source of Variation	D/F
Level of WHEAPRO (L)	3
Linear effects (l)	
Judges (J)	8
L x J	24
Error	108
Total	143

If a significant F-value was found, least significant differences (LSD, $P < 0.05$) were calculated.

The method of orthagonal comparison was used to determine the response to changes in level of WHEAPRO.

The data for measurements used to evaluate objective values also were analyzed. The plan for that analysis was:

Source of Variation	D/F
Replications	15
Treatment	3
Error	29
Total	47

Least significant differences (LSD, $P < 0.05$) also were calculated if a significant F-value was found.

RESULTS AND DISCUSSION

Values for objective measurements and palatability scores appear in Appendix, Tables 6-19. The analyses of variance also appear in Appendix, Tables 20-21. Throughout the discussion, the treatment containing 0% WHEAPRO will be referred to as A; 10% as B; 20% as C; and 50% as D.

Objective Measurements

Cooking Loss. The average cooking loss increased, but not always significantly as the percentage of WHEAPRO increased (Table 4). The differences between treatments B and C were not significant, but differences between other treatments were significant ($P < 0.05$). The dough became more extensible but was less elastic as the percentage of WHEAPRO was increased, then with the lowered elasticity there was increased surface area exposed to heat. This could have been a contributing factor to the increased cooking losses.

Percentage Total Moisture. The average percentage total moisture as determined in the C. W. Brabender semi-automatic rapid moisture tester decreased as the percentage of WHEAPRO increased (Table 4). Only treatment D had significantly ($P < 0.05$) less total moisture than the others (treatments A, B and C). The dough elasticity might have been a contributing factor here also as it appeared to be with the cooking losses. Another factor might be the difference in rates of absorption between WHEAPRO and whole wheat flour. The WHEAPRO was very dry and when placed

Table 4. Average objective values and significant differences for chapatis.

Factors	Average values for treatments[a] A	B	C	D	LSD[b]
Cooking loss	14.597 *	14.991	15.272 *	15.916	0.325
	└────	────	* ────	* ┘	
		└────	────	* ┘	
Percentage total moisture	33.691	33.499	33.308 *	32.637	0.409
	└────	────	────	* ┘	
		└────	────	* ┘	
Color: Rd	21.493 *	20.071	19.172 *	15.564	1.102
	└────	────	* ────	* ┘	
		└────	────	* ┘	
Color: a/b	0.393	0.374	0.379 *	0.439	0.037
	└────	────	────	* ┘	
		└────	────	* ┘	
pH	6.394 *	6.339 *	6.317 *	6.293	0.021
	└────	────	* ────	* ┘	
		└────	────	* ┘	
Volume	47.188	49.062	49.375	56.875	7.854
	└────	────	────	* ┘	

[a]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

[b]Least significant difference; *, $P < 0.05$.

on the tongue, as a powder, left a dry feeling for a longer period than did the whole wheat flour. Thus, WHEAPRO seemed to be more absorptive than whole wheat flour.

Color. An objective color measurement was made with the Gardner color-difference meter. In Table 4 the differences in reflectance (Rd) values attributable to WHEAPRO were significant ($P < 0.05$) in all cases, except the difference between treatments B and C was not significant. The values decreased indicating increased amount of light absorbed, with each percentage increment of WHEAPRO following a downward pattern. The trend for less reflectance with greater amounts of WHEAPRO supports the concept that greater brownness is associated with increased percentage of WHEAPRO. The WHEAPRO was a browner color than the whole wheat flour, thus a browner dough and product resulted as increasing amounts of WHEAPRO were used.

The degree of redness (a/b) values, in which a+ = redness and b+ = yellowness, varied and only the value for treatment D was significantly ($P < 0.05$) higher than that for each of the others (Table 4). The average value for treatment A was slightly higher than the average values for treatments B and C, but the differences were not significant. The explanation for this was not clear. Undoubtedly when as much as 50% WHEAPRO was used, there was a difference in color.

pH. The pH of the dough decreased significantly ($P < 0.05$) as the percentage of WHEAPRO increased (Table 4). From this comes the assumption that the WHEAPRO is more acid than the whole wheat flour. The increased acidity of the dough with increased WHEAPRO could be related to the decreased elasticity of the dough for as acidity is increased, gluten strength is decreased.

Volume. The volume varied considerably among samples at the same levels. The only significant ($P < 0.05$) difference in volume noted overall was between treatments A and D (Table 4). The volume varied as the puffing was not always the same; in some cases where the puff was complete the chapati would collapse as it cooled and thus would yield a much smaller volume than was actually the case when the chapati was hot. Volume was not measured until the chapati had cooled for a given time, as the moisture condensation which occurred while it was hot interfered with the volume measurement.

To summarize the objective measurements, an evident relationship between cooking loss and percentage total moisture appeared. The cooking losses increased as the percentage total moisture decreased.

Subjective Measurements

There were certain limitations and difficulties involved in the organoleptic phase of the present study. During the preliminary work it was found that each Indian student had a different idea of a standard chapati and it was somewhat difficult to be unbiased in scoring. Their judgments were based on comparisons with the chapatis eaten in their own homes, and it is known that chapatis vary within sections of India and even from household to household in the same area. The chapati used as the control product in this study was most typical of one made in the area of Hyderabad, A.P., India.

It was planned to use an entire Indian panel to score the chapatis; however, only 3 members came regularly enough during the early study to be considered for the actual panel. Hence, it was necessary to recruit other members from within the Department of Foods and Nutrition, who were able to taste regularly. A training period ensued for the panel who scored the final products. Samples were to be scored within a 2 hour period. Judges were asked to come at their convenience within this time but to come regularly if they could participate. It was important that products be scored at as nearly the same time as possible from day to day because the chapati became leathery as it set. The scoring was based on a scale ranging from 7 (very desirable) to 1 (very undesirable) (Form 1, Appendix).

Appearance. The average appearance scores decreased as the percentage of WHEAPRO increased; although the only significant ($P < 0.05$) differences noted were between treatments A and D, and B and D (Table 5). Some taste panel members objected to the overcooked appearance of the chapatis with treatment D. Comments ranged from "too dark" to "burnt". In Table 21, Appendix, there was noted a linear response to the changes in the level of WHEAPRO on the average appearance scores which was highly significant ($P < 0.01$).

Color. The average color scores varied with the treatments,

Table 5. Average palatability scores and significant differences for chapatis.

Factors	Average scores[a] for treatments[b]				LSD[c]
	A	B	C	D	
Appearance	6.072	6.042	5.978	5.803	0.221
				*	
				*	
Color	5.728	5.922	5.892 *	5.161	0.204
				*	
				*	
Tenderness	5.794	5.697	5.664	5.469	0.268
				*	
Moisture content	5.972	5.797	5.764 *	5.458	0.230
				*	
				*	
Texture	6.039	5.878	5.858 *	5.625	0.212
				*	
				*	
Flavor	5.961	5.997 *	5.636 *	5.275	0.186
			*	*	
				*	

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

[c]Least significant difference; *, P < 0.05.

in the following order: B, C, A, and D, from highest to lowest (Table 5). There were significant ($P < 0.05$) differences between treatments A and D, B and D, and C and D. The main comment made by the judges was that treatment D was too dark. A few commented that treatment A was too light or pale. Treatments B and C looked similar in color. Apparently the WHEAPRO was the contributing factor relating to the darkness of the sample for as the WHEAPRO increased so did the degree of brownness. The very highly significant ($P < 0.001$) linear effect of the average color scores was ascribed to increased levels of WHEAPRO incorporated into the chapatis (Table 21, Appendix).

Tenderness. In Table 5 the average tenderness scores decreased with increased WHEAPRO, but the only significant ($P < 0.05$) difference was between treatments A and D. One of the taste panel members from India noted that treatment D "breaks away abruptly, not characteristic". The average tenderness scores attributed to changes in the level of WHEAPRO showed a significant ($P < 0.05$) linear effect (Table 21, Appendix).

Moisture Content. Average moisture content scores also decreased as the percentage of WHEAPRO increased. The differences were significant ($P < 0.05$) between treatments A and D, B and D, and C and D (Table 5). The comments regarding the moisture content varied for the same treatment on different days for a single judge and even on the same day between judges. These differences were noted mainly in the comments of the judges, i.e., one sample would be considered dry by one judge and soggy by another judge on the same day. Treatment D was noted as being slightly dry when comments regarding it were made. The effect of the levels of WHEAPRO on average moisture content scores was very highly significantly ($P < 0.001$) linear (Table 21, Appendix).

Texture. The average texture scores decreased as the percentage of WHEAPRO increased. Significant ($P < 0.05$) differences as shown in Table 5 were noted between treatments A and D, B and D, and C and D. Very few comments were made on texture by the judges. One judge sometimes did note treatments B and D as being grainy. There was a very highly significant ($P < 0.001$) linear effect on average texture scores attributable to levels of WHEAPRO (Table 21, Appendix).

Flavor. The average flavor scores varied with those for treatment B being the highest followed by those of A, C, and D in that order (Table 5). There were significant ($P < 0.05$) differences noted between treatments A and C, A and D, B and C, B and D, and C and D. Treatment A was preferred by some while others thought it had a slightly raw taste, B was generally well received, whereas C was ranked lower for its bitter taste. However, some of the taste panel members liked C best. Treatment D was discriminated against for its bitter aftertaste by many of the judges although one judge thought it had a richer flavor. The average flavor scores indicated that the linear response to levels of WHEAPRO was very highly significant ($P < 0.001$) (Table 21, Appendix).

The values for cooking loss and percentage total moisture as well as the subjective scores for moisture content decreased as the percentage of WHEAPRO increased. The moisture scores decreased as did the tenderness scores.

The comments of the judges denoted a similarity between the objective values and subjective scores for color. The reflectance (Rd) values indicated treatment A absorbed the least light and D absorbed the most. The judges noted that treatment A was too pale and D was too dark. The appearance scores may have been affected by the color according to the comments of the judges.

Generally, there was little difference in the average scores of the chapatis for treatments A, B and C when considering appearance, color, tenderness, moisture content and texture. The flavor of treatments A and B was scored significantly higher than that for treatments C and D; and treatment B was scored higher than treatment A, although not significantly. For the most part treatment D was scored significantly lower than any other treatment for all palatability factors. Thus, it appeared that treatments A, B and possibly C would be acceptable.

Further studies concerned with other levels of WHEAPRO might be explored. Varying proportions of salt to counteract the bitter flavor of WHEAPRO might be investigated also.

SUMMARY

The cooking loss increased as the percentage of WHEAPRO increased but not always significantly. Both the percentage total moisture and the pH of the dough decreased as the percentage of

WHEAPRO increased. The value for percentage total moisture of treatment D was significantly less than that for each of the other levels of WHEAPRO; whereas the differences in pH were significant in all cases. The differences in reflectance (Rd) values of the chapatis attributable to WHEAPRO were significant except between treatments B and C. The degree of redness (a/b) values varied, and only the value for treatment D was significantly higher than that for each of the others. The only significant difference in volumes noted overall was between treatments A and D. The cooking loss was highest and the percentage total moisture lowest for treatment D.

The average appearance, tenderness, moisture content and texture scores all decreased as the percentage of WHEAPRO increased. The color scores varied with the treatments but the differences were not always significant. There were significant differences noted in flavor scores except between treatments A and B. For the most part, when 50% WHEAPRO was substituted for an equal weight of whole wheat flour, the chapatis were scored significantly lower than those containing each of the other 3 levels and, generally, were not well received. Thus, it appeared that treatments A, B and possibly C would be acceptable. Overall, there was a significant linear response to changes in level of WHEAPRO for all palatability factors.

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APPENDIX

Form 1. Score card for chapatis.

Name ______________________ Date ______________________

Factor (characteristic)	Sample			Comments
	1	2	3	
Appearance - evenly rolled, circular shape, well-cooked				
Color - mottled brown surface with some dark areas or spots				
Tenderness - tender, not tough				
Moisture content - moist but not soggy. Not dry.				
Texture - chewy				
Flavor - pleasing, characteristic, not raw tasting				

Scoring Key:
- 7 Very desirable
- 6 Desirable
- 5 Moderately desirable
- 4 Neutral
- 3 Slightly undesirable
- 2 Undesirable
- 1 Very undesirable

Form 2. Design for preparation and evaluation of chapatis.

Preparation and evaluation period for samples	Treatment[a]			
	A	B	C	D
1	X	X	X	
2		X	X	X
3	X	X		X
4	X		X	X
5	X	X		X
6	X	X	X	
7	X		X	X
8		X	X	X
9	X	X		X
10	X		X	X
11	X	X	X	
12		X	X	X
13	X	X	X	
14	X	X		X
15		X	X	X
16	X		X	X

[a]Treatments: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 6. Mean percentage cooking loss for duplicate samples of chapatis.

Sample	Treatment[a]			
	A	B	C	D
1	13.5	13.8	14.4	
2		13.0	13.4	15.2
3	15.4	15.7		16.0
4	14.8		15.5	16.1
5	13.6	15.4		15.0
6	14.4	15.0	14.9	
7	15.1		15.6	16.1
8		15.4	15.6	16.2
9	15.0	15.2		16.4
10	14.4		15.4	16.0
11	15.4	15.5	16.0	
12		14.0	15.2	15.8
13	14.8	14.8	15.4	
14	14.6	15.6		16.1
15		15.8	15.8	16.8
16	15.0		15.4	15.8
Av.	14.7	15.0	15.2	16.0

[a]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 7. Mean percentage total moisture content for duplicate samples of chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	34.10	34.93	34.28	
2		34.34	34.59	33.11
3	33.41	32.92		31.68
4	34.15		33.44	33.14
5	34.34	33.20		33.36
6	34.01	33.05	32.94	
7	33.15		33.58	32.48
8		33.28	33.08	31.88
9	33.84	32.74		32.46
10	33.34		33.00	33.13
11	33.22	33.34	32.93	
12		34.04	33.49	32.42
13	33.73	33.80	32.62	
14	33.28	32.80		31.75
15		33.42	33.89	32.42
16	33.00		33.04	33.50
Av.	33.63	33.49	33.40	32.61

[a]Brabender moisture tester readings.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 8. Color: reflectance (Rd) values for chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	19.72	18.23	19.10	
2		20.23	18.34	16.12
3	21.56	20.70		16.06
4	20.72		18.44	15.82
5	22.09	20.80		14.40
6	20.93	20.04	19.00	
7	22.86		20.12	16.76
8		19.62	19.66	13.24
9	21.85	21.84		16.45
10	22.06		19.49	16.05
11	22.02	21.07	19.20	
12		21.29	18.52	13.96
13	23.52	15.94	20.33	
14	21.72	19.86		17.31
15		20.64	17.50	16.04
16	20.22		18.32	15.84
Av.	21.61	20.02	19.00	15.67

[a]Gardner Color-Difference Meter measurement.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 9. Color: redness (a+) values for chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	5.21	4.94	5.58	
2		5.05	5.10	7.50
3	5.84	5.32		6.32
4	5.58		5.76	5.95
5	6.18	6.69		6.50
6	6.80	6.20	7.46	
7	6.98		6.86	7.26
8		6.11	5.60	6.28
9	7.20	5.77		6.60
10	5.63		5.04	6.74
11	5.80	4.79	5.24	
12		6.44	5.87	6.82
13	6.00	6.96	6.53	
14	5.74	5.73		7.34
15		6.60	7.68	5.80
16	5.54		4.77	7.03
Av.	6.04	5.88	5.96	6.68

[a]Gardner Color-Difference Meter measurement.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 10. Color: yellowness (b+) values for chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	14.92	14.82	15.29	
2		16.04	16.52	15.92
3	15.20	15.28		15.24
4	15.01		15.56	14.87
5	15.70	16.50		14.84
6	15.20	15.18	15.50	
7	16.46		16.32	16.14
8		15.54	15.78	13.10
9	15.74	15.79		15.80
10	16.07		16.16	15.98
11	15.46	16.07	15.04	
12		15.75	15.31	14.48
13	15.22	14.22	16.10	
14	15.08	15.06		16.15
15		15.44	15.37	15.18
16	15.37		15.09	15.48
Av.	15.45	15.48	15.67	15.26

[a]Gardner Color-Difference Meter measurement.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 11. Color: degree of redness (a/b) values for chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	.35	.33	.36	
2		.31	.31	.47
3	.38	.35		.41
4	.37		.37	.40
5	.39	.40		.44
6	.45	.41	.48	
7	.42		.42	.45
8		.39	.35	.48
9	.46	.36		.41
10	.35		.31	.42
11	.38	.30	.35	
12		.41	.38	.47
13	.39	.49	.40	
14	.38	.38		.45
15		.43	.50	.38
16	.36		.32	.45
Av.	.39	.38	.38	.44

[a]Calculated from Gardner Color-Difference Meter measurements.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 12. pH of chapati dough.[a]

Sample	Treatment[b]			
	A	B	C	D
1	6.38	6.40	6.36	
2		6.32	6.28	6.28
3	6.38	6.36		6.26
4	6.40		6.30	6.28
5	6.41	6.31		6.29
6	6.43	6.40	6.32	
7	6.40		6.30	6.30
8		6.32	6.38	6.28
9	6.38	6.32		6.30
10	6.38		6.32	6.30
11	6.42	6.32	6.32	
12		6.31	6.31	6.29
13	6.42	6.37	6.30	
14	6.36	6.32		6.28
15		6.32	6.32	6.28
16	6.40		6.34	6.30
Av.	6.40	6.34	6.32	6.29

[a]Beckman Model 76 Expanded Scale pH meter readings.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 13. Volume of chapatis.[a]

Sample	Treatment[b]			
	A	B	C	D
1	50	50	50	
2		50	50	60
3	70	60		60
4	50		55	65
5	60	40		60
6	45	50	45	
7	40		45	50
8		45	30	35
9	50	50		65
10	45		55	55
11	40	60	75	
12		45	50	50
13	55	40	30	
14	40	40		70
15		60	40	50
16	40		50	60
Av.	49	49	48	57

[a]Seed displacement measurements in cc.

[b]Treatment: A = 0% WHEAPRO

B = 10% WHEAPRO

C = 20% WHEAPRO

D = 50% WHEAPRO

Table 14. Appearance scores for chapatis.[a]

Judge	Treatment[b]	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av
1																		
	A	7		6	6	7	-[c]	7		7	7	7		7	7		7	6.8
	B	6	7	7		7	-		5	7		7	6	7	6	7		6.5
	C	6	7		5		-	6	5		7	7	6	6		6	6	6.1
	D		6	5	5	6		6	5	7	6		6		6	6	6	5.8
2																		
	A	6		6	6	6	6	6		6	-	6		6	6		6	6.0
	B	5	6	6		6	6		6	6		6	6	6	6	6		5.9
	C	4	6		6		5	6	5		-	6	6	6		6	6	5.6
	D		5	6	6	6		5	6	5	-		6		4	5	4	5.3
3																		
	A	6		7	7	7	7	7		7	7	7		7	-		7	6.9
	B	6	7	7		7	7		7	7		7	7	7	-	7		6.9
	C	6	6		7		7	7	7		7	7	7	7		7	7	6.8
	D		5	7	7	7		7	7	7	7		7		-	7	7	6.8
4																		
	A	4		5	4	4	6	7		5	5	6		6	6		6	5.3
	B	3	5	6		5	4		3	3		5	6	5	5	6		4.7
	C	5	6		6		5	5	6		6	4	6	4		5	3	5.1
	D		5	4	5	4		6	4	6	4		3		3	4	4	4.3
5																		
	A	5		5	6	6	6	6		6	6	6		6	6		6	5.8
	B	6	6	6		6	6		6	6		6	6	6	6	6		6.0
	C	6	6		6		6	6	6		6	6	6	5		5	6	5.8
	D		6	5	6	6		6	5	5	5		6		5	4	5	5.3
6																		
	A	5		7	7	5	5	5		6	7	-		5	-		6	5.8
	B	5	5	7		6	5		6	6		-	7	7	-	6		6.0
	C	5	5		7		6	5	5		7	-	7	7		6	6	6.0
	D		5	6	5	5		5	5	5	7		6		-	6	5	5.4
7																		
	A	7		4	5	6	7	7		7	6	5		5	4		4	5.6
	B	6	7	5		5	6		7	7		5	6	7	6	6		6.1
	C	6	7		6		6	6	6		6	5	6	7		5	5	5.9
	D		5	7	7	7		7	7	6	7		6		7	5	7	6.5
8																		
	A	5		5	6	-	7	6		6	6	7		5	5		5	5.7
	B	6	6	6		-	5		5	5		6	5	6	6	5		5.5
	C	4	7		5		6	7	6		6	7	6	7		6	6	6.1
	D		5	7	7	-		5	7	7	7		7		7	7	7	6.6
9																		
	A	7		7	6	6	7	6		-	-	7		6	6		7	6.5
	B	6	7	7		7	6		7	-		6	7	7	6	7		6.6
	C	6	6		6		6	6	7		-	7	7	6		6	6	6.3
	D		7	6	6	6		7	6	-	-		6		5	6	6	6.1

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHEAPRO; C = 20% WHEAPRO; D = 50% WHEAPRO.

[c]- : Missing data.

Table 15. Color scores for chapatis.[a]

Judge	Treat-ment[b]	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
1																		
	A	7		5	6	7	–[c]	7		6	7	7		7	7		7	6.6
	B	6	7	6		7	–		6	7		7	6	7	6	7		6.5
	C	6	6		5		–	6	6		7	7	5	6		6	6	6.0
	D		6	3	4	6		5	5	5	6		4		5	5	5	4.9
2																		
	A	6		6	6	5	5	5		6	–	6		6	5		6	5.6
	B	5	6	6		6	6		6	6		6	5	7	6	6		5.9
	C	5	5		6		6	6	5		–	5	6	5		6	6	5.5
	D		5	5	5	6		5	5	5	–		5		6	5	5	5.2
3																		
	A	6		7	7	7	7	7		7	7	7		7	–		7	6.9
	B	6	7	6		6	6		6	6		6	7	7	–	7		6.4
	C	5	6		6		3	6	7		6	3	6	5		6	6	5.4
	D		5	3	3	3		3	3	3	3		3		–	3	3	3.2
4																		
	A	3		4	3	2	5	6		6	5	5		4	4		5	4.3
	B	5	3	6		4	3		5	5		6	6	5	5	6		4.9
	C	6	5		7		4	5	3		7	3	5	6		5	6	5.2
	D		4	5	4	5		4	4	4	5		4		3	3	3	4.0
5																		
	A	6		5	6	6	5	5		6	6	6		6	6		6	5.8
	B	6	6	6		6	6		6	6		6	6	6	6	6		6.0
	C	6	6		6		6	6	6		6	5	6	5		6	6	5.8
	D		6	5	5	5		4	5	5	5		5		5	4	5	4.9
6																		
	A	5		6	6	6	6	5		6	6	–		7	–		6	5.9
	B	5	5	7		6	5		6	5		–	6	7	–	6		5.8
	C	5	6		7		5	6	6		7	–	7	6		7	7	6.3
	D		4	5	5	5		4	5	4	5		6		–	5	5	4.8
7																		
	A	6		5	4	5	5	5		4	5	4		5	4		4	4.7
	B	6	4	4		6	7		6	5		5	5	5	5	5		5.3
	C	7	5		6		7	6	6		6	6	5	6		6	5	5.9
	D		7	7	7	7		7	7	6	7		7		7	7	7	6.9
8																		
	A	4		5	6	–	4	4		5	5	5		5	5		6	4.9
	B	5	7	6		–	6		5	6		6	5	6	6	5		5.7
	C	6	5		5		7	6	5		6	7	6	7		6	7	6.1
	D		6	7	7	–		5	6	7	7		7		7	7	6	6.5
9																		
	A	6		7	7	7	7	6		–	–	7		7	6		7	6.7
	B	5	7	7		7	6		7	–		7	7	7	6	7		6.6
	C	6	6		7		6	7	7		–	7	7	7		7	6	6.6
	D		7	6	6	6		7	6	–	–		6		5	6	6	6.1

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHEAPRO; C = 20% WHEAPRO; D = 50% WHEAPRO.

[c] –: Missing data.

Table 16. Tenderness scores for chapatis.[a]

Judge	Treat-ment[b]	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
1																		
	A	6		7	5	6	–[c]	6		6	6	7		6	7		6	6.2
	B	7	6	7		7	–		6	5		6	6	5	6	6		6.1
	C	6	6		5		–	6	6		6	6	6	6		6	5	5.8
	D		6	6	6	6		7	5	6	6		4		7	6	6	5.9
2																		
	A	6		6	6	5	5	6		6	–	6		6	5		6	5.7
	B	7	–	6		6	6		5	6		6	–	6	6	5		5.9
	C	6	–		6		5	5	5		–	6	–	6		6	5	5.6
	D		–	5	5	5		5	6	6	–		–		6	5	5	5.3
3																		
	A	6		7	7	6	7	6		6	7	6		6	–		6	6.4
	B	6	7	6		6	6		6	6		6	6	6	–	7		6.2
	C	6	6		6		6	6	6		6	5	6	6		7	6	6.0
	D		5	6	5	5		5	6	5	5		3		–	3	4	4.7
4																		
	A	4		4	5	5	5	5		5	6	6		1	3		5	4.5
	B	6	5	7		3	4		4	1		3	5	5	2	3		4.0
	C	2	7		7		3	3	5		2	4	3	7		1	6	4.2
	D		6	4	5	6		3	2	4	5		5		6	5	2	4.4
5																		
	A	6		6	6	6	6	6		6	6	6		6	6		5	5.9
	B	5	5	6		6	6		6	6		6	6	6	6	6		5.8
	C	5	6		5		6	6	6		6	5	6	6		6	5	5.7
	D		6	6	5	5		6	5	6	5		6		5	6	5	5.5
6																		
	A	4		7	7	4	5	6		6	6	–		6	–		7	5.8
	B	4	4	6		5	4		6	6		–	6	6	–	7		5.4
	C	5	5		6		5	5	5		6	–	7	7		6	6	5.7
	D		5	6	6	5		4	5	5	5		6		–	6	6	5.4
7																		
	A	6		7	7	5	6	5		6	6	7		6	4		6	5.9
	B	7	7	6		6	5		7	7		5	5	7	6	6		6.2
	C	6	5		6		6	7	7		4	7	7	6		5	7	6.1
	D		6	7	6	7		7	6	7	7		6		7	5	6	6.4
8																		
	A	5		7	6	–	7	4		7	7	6		7	6		7	6.3
	B	6	4	6		–	5		7	5		4	7	5	4	5		5.3
	C	4	7		5		6	6	6		5	5	6	6		7	6	5.8
	D		6	5	7	–		7	4	6	6		5		7	6	5	5.8
9																		
	A	6		5	5	7	5	6		–	–	5		6	5		6	5.6
	B	6	7	5		7	6		6	–		6	6	6	6	6		6.1
	C	5	5		6		7	7	7		–	6	6	6		6	5	6.0
	D		6	6	6	6		7	6	–	–		5		6	5	6	5.9

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHEAPRO; C = 20% WHEAPRO; D = 50% WHEAPRO.

[c] –: Missing data

Table 17. Moisture content scores for chapatis.[a]

Judge	Treat-ment[b]	Period																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
1																		
	A	7		7	6	6	-[c]	7		7	6	7		6	7		7	6.6
	B	7	7	7		7	-		6	6		6	6	6	6	6		6.4
	C	6	6		6		-	7	6		6	6	6	6		7	6	6.2
	D		6	6	6	6		6	5	5	5		4		6	6	6	5.6
2																		
	A	4		6	6	6	6	6		-	-	6		-	6		6	5.8
	B	6	6	6		5	6		-	-		6	6	-	6	5		5.8
	C	4	5		6		5	6	-		-	5	6	-		6	5	5.3
	D		6	5	5	4		5	-	-	-		5		5	5	5	5.0
3																		
	A	6		7	7	7	7	7		6	7	7		7	-		7	6.8
	B	6	7	6		6	6		6	6		6	6	7	-	7		6.3
	C	6	6		6		6	6	6		6	5	6	7		7	6	6.1
	D		6	5	5	6		5	3	5	5		6		-	6	5	5.2
4																		
	A	4		6	4	3	6	5		6	5	6		2	5		6	4.8
	B	5	6	7		5	6		6	4		4	4	6	4	6		5.2
	C	3	2		5		4	4	6		3	5	3	7		4	6	4.3
	D		5	5	6	4		5	3	6	4		6		6	6	2	4.8
5																		
	A	6		6	6	6	6	5		6	6	6		6	6		6	5.9
	B	6	6	6		6	6		6	5		6	5	5	5	5		5.6
	C	6	6		6		6	6	6		6	5	5	5		5	6	5.7
	D		6	5	5	5		5	5	4	5		4		5	5	6	5.0
6																		
	A	5		6	7	4	6	5		6	6	-		6	-		6	5.7
	B	5	5	7		6	5		6	7		-	7	5	-	7		6.0
	C	6	6		6		6	6	6		6	-	6	7	-	6	6	6.1
	D		5	7	6	5		5	5	6	6		5		-	7	6	5.7
7																		
	A	5		5	7	7	5	5		5	5	4		6	5		4	5.2
	B	5	5	6		7	5		7	5		6	5	5	6	5		5.6
	C	7	6		4		7	7	7		5	7	6	7		6	7	6.3
	D		7	7	6	6		6	7	7	7		7		7	5	5	6.4
8																		
	A	6		7	7	-	7	4		6	6	6		7	6		7	6.3
	B	5	4	6		-	4		6	4		4	7	5	4	6		5.0
	C	3	7		6		5	5	5		4	6	6	6		7	7	5.6
	D		6	5	6	-		6	4	5	5		5		7	5	6	5.4
9																		
	A	7		6	6	7	6	6		-	-	7		6	6		6	6.3
	B	6	7	6		7	6		7	-		6	6	6	6	6		6.3
	C	6	6		6		7	6	6		-	6	7	6		6	6	6.2
	D		6	6	6	5		7	6	-	-		6		5	6	6	5.9

[a]Range: 7(very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHEAPRO; C = 20% WHEAPRO; D = 50% WHEAPRO.

[c] -: Missing data.

Table 18. Texture scores for chapatis.[a]

Judge	Treatment[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
1																		
	A	7		7	6	7	-[c]	7		7	7	7		6	7		7	6.8
	B	7	7	7		7	-		7	6		6	7	6	7	7		6.7
	C	6	7		6		-	7	6		6	7	7	7		6	6	6.4
	D		6	6	6	7		7	6	6	6		6		7	7	6	6.3
2																		
	A	6		5	5	5	-	5		6	-	6		6	5		5	5.4
	B	6	5	5		5	-		6	5		6	6	6	6	5		5.5
	C	5	5		5		-	5	6		-	6	6	5		5	5	5.3
	D		6	6	6	6		6	6	4	-		6		5	6	6	5.7
3																		
	A	6		6	7	7	7	7		6	7	7		7	-		7	6.7
	B	6	7	6		6	6		6	6		6	7	7	-	6		6.3
	C	6	6		6		5	6	6		6	5	7	7		6	6	6.0
	D		3	5	6	5		5	3	5	5		6		-	5	5	4.8
4																		
	A	5		5	5	6	6	5		6	6	6		3	5		6	5.3
	B	6	6	7		4	6		6	2		4	6	6	4	6		5.2
	C	3	6		6		5	5	6		3	5	5	7		6	6	5.2
	D		6	5	7	6		5	5	5	5		6		5	5	4	5.3
5																		
	A	6		6	6	6	6	6		6	6	6		6	6		6	6.0
	B	6	6	6		6	6		6	6		6	6	6	6	6		6.0
	C	6	6		6		6	6	6		6	6	6	6		6	6	6.0
	D		6	5	6	6		6	5	6	5		5		6	6	6	5.7
6																		
	A	5		7	6	4	5	5		6	6	-		5	-		6	5.5
	B	4	4	6		5	4		7	6		-	6	5	-	7		5.4
	C	6	5		7		5	6	6		6	-	6	6		6	7	6.0
	D		5	6	6	5		5	5	5	5		5		-	6	6	5.4
7																		
	A	7		6	7	7	7	6		6	4	5		7	5		6	6.1
	B	5	6	5		5	6		7	7		5	5	7	7	4		5.8
	C	7	5		5		7	7	7		5	6	6	6		6	7	6.2
	D		7	7	6	6		7	7	6	7		7		6	4	6	6.3
8																		
	A	6		7	7	-	6	6		5	7	7		7	6		7	6.4
	B	5	6	6		-	5		7	4		5	6	6	5	7		5.6
	C	4	5		6		4	5	6		6	6	6	7		6	6	5.6
	D		5	5	5	-		5	5	6	4		5		5	6	5	5.1
9																		
	A	7		5	6	6	6	6		-	-	6		6	5		6	5.9
	B	6	7	5		7	6		7	-		6	6	6	6	6		6.2
	C	6	5		6		6	6	6		-	6	6	6		6	6	5.9
	D		6	6	6	5		7	6	-	-		6		5	6	6	5.9

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHFAPRO; C= 20% WHEAPRO; D = 50% WHEAPRO.

[c] -: Missing data.

Table 19. Flavor scores for chapatis.[a]

Judge	Treatment[b]	Period 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
1																		
	A	6.5		6.0	6.5	6.5	-[c]	7.0		6.5	7.0	7.0		7.0	7.0		7.0	6.7
	B	6.5	7.0	7.0		7.0	-		6.0	6.5		6.5	7.0	6.5	7.0	7.0		6.7
	C	7.0	6.0		6.5		-	7.0	6.0		6.5	6.5	6.0	7.0		7.0	6.5	6.5
	D		6.0	5.0	6.5	7.0		6.5	6.5	6.0	4.0		4.0		7.0	6.0	5.0	5.8
2																		
	A	6.0		6.0	6.0	5.5	6.0	6.0		6.0	-	6.0		6.0	6.0		6.0	6.0
	B	6.0	6.0	6.0		6.0	5.0		6.0	5.5		6.0	6.0	6.0	6.0	5.5		5.8
	C	5.0	3.0		5.5		4.5	6.0	5.0		-	4.0	6.0	4.0		6.0	4.5	4.9
	D		2.0	4.0	4.0	5.5		4.0	4.0	4.0	-		4.0		4.0	3.0	4.5	3.9
3																		
	A	7.0		7.0	7.0	7.0	7.0	7.0		7.0	7.0	7.0		7.0	-		7.0	7.0
	B	7.0	7.0	7.0		7.0	6.5		7.0	6.5		6.5	7.0	7.0	-	7.0		6.9
	C	5.0	6.5		6.5		4.0	6.5	7.0		6.5	5.0	6.5	6.0		7.0	6.0	6.0
	D		5.0	4.5	6.0	5.0		4.5	5.0	5.0	5.0		5.0		-	6.0	5.0	5.1
4																		
	A	4.5		6.0	5.0	5.5	6.0	3.5		4.5	6.5	5.5		3.0	6.0		5.0	5.1
	B	5.5	3.5	7.0		4.0	6.5		5.5	5.5		4.5	5.0	5.0	5.0	4.0		5.1
	C	3.0	4.5		7.0		4.0	4.5	5.5		4.0	7.0	4.0	6.0		3.0	6.0	4.9
	D		5.5	6.0	7.0	6.5		5.5	4.5	6.5	7.0		4.5		6.0	6.0	3.0	5.7
5																		
	A	5.0		6.0	6.0	6.0	6.0	6.0		6.0	6.0	6.0		6.0	6.0		6.0	5.9
	B	6.0	6.0	5.0		5.5	6.0		6.0	4.5		5.0	6.0	5.5	5.5	6.0		5.6
	C	4.0	5.5		4.5		4.5	5.0	5.0		6.0	5.0	4.5	4.5		4.5	4.5	4.8
	D		4.5	3.5	3.5	4.0		3.5	3.5	4.0	3.5		4.0		3.5	3.5	3.5	3.7
6																		
	A	5.0		6.5	6.0	5.0	5.0	5.0		7.0	6.5	-		5.5	-		6.0	5.8
	B	5.0	5.0	6.5		5.0	5.0		6.5	6.0		-	6.5	6.0	-	6.5		5.8
	C	5.0	4.5		7.0		6.0	6.0	6.5		6.5	-	6.5	6.0		6.5	5.5	6.0
	D		5.5	6.0	6.0	5.0		4.5	5.0	5.5	5.5		5.5		-	6.0	7.0	5.6

Table 19. (concluded)

Judge	Treat-ment[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Av.
7																		
	A	5.5		4.0	4.0	6.0	5.0	5.0		5.0	6.0	4.0		5.0	4.0		4.0	4.8
	B	7.0	6.5	5.0		5.0	7.0		7.0	6.0		5.0	6.0	5.0	6.0	5.0		5.9
	C	6.0	6.5		7.0		6.5	7.0	6.0		6.0	6.0	6.0	6.0		6.0	6.0	6.2
	D		4.0	6.0	6.0	6.0		6.0	6.0	7.0	7.0		7.0		6.5	7.0	7.0	6.3
8																		
	A	5.0		6.0	6.0	-	6.0	5.0		6.0	6.5	6.0		6.0	6.0		6.0	5.9
	B	5.0	5.5	6.5		-	5.5		6.0	5.5		6.0	5.5	6.0	6.0	6.0		5.8
	C	3.5	5.5		6.0		5.0	6.0	5.5		5.5	5.5	6.0	5.5		6.0	6.0	5.5
	D		5.0	6.5	6.5	-		6.5	5.0	5.0	5.0		6.0		6.5	7.0	5.5	5.9
9																		
	A	6.5		6.0	6.0	7.0	6.0	6.5		-	-	6.5		7.0	6.0		7.0	6.4
	B	6.0	7.0	6.0		7.0	6.0		7.0	-		6.0	7.0	6.0	6.0	6.0		6.4
	C	5.0	7.0		7.0		6.0	6.5	6.5		-	5.0	7.0	6.0		6.0	6.0	6.2
	D		5.5	5.0	6.0	6.0		5.5	5.5	-	-		5.5		5.0	5.5	5.5	5.5

[a]Range: 7 (very desirable) to 1 (very undesirable).

[b]Treatment: A = 0% WHEAPRO; B = 10% WHEAPRO; C = 20% WHEAPRO; D = 50% WHEAPRO.

[c] -: Missing data.

Table 20. Analyses of variance for objective values of chapatis.

Source	D/F	MS	F-value	Sig.[a]
Cooking loss				
Treatment	3	3.2879	24.4303	***
Error	29	0.1346		
Percentage total moisture				
Treatment	3	2.2443	10.4975	***
Error	29	0.2138		
Color: Rd				
Treatment	3	68.1756	44.0063	***
Error	29	1.5492		
Color: a/b				
Treatment	3	0.0092	5.4003	**
Error	29	0.0017		
pH				
Treatment	3	0.0196	34.3624	***
Error	29	0.0006		
Volume (cc.)				
Treatment	3	195.1389	2.4807	ns
Error	29	78.6638		

[a]***, $P < 0.001$
**, $P < 0.01$
ns, not significant.

Table 21. Analyses of variance for palatability scores of chapatis.

Source	D/F	MS	F-values	Sig.[a]
Appearance				
Level of WHEAPRO (L)	3	0.5227	2.3375	ns
Linear effect (l)		1.5556	6.9564	**
Judges (J)	8	4.9753	22.2497	***
L x J	24	0.4750	2.1241	*
Error	108	0.2236		
Total	143			
Color				
Level of WHEAPRO (L)	3	4.4991	23.4766	***
Linear effect (l)		9.2286	48.1550	***
Judges	8	4.2557	22.2063	***
L x J	24	2.4410	12.7373	***
Error	108	0.1916		
Total	143			
Tenderness				
Level of WHEAPRO (L)	3	0.6688	2.0216	ns
Linear effect (l)		1.9813	5.9891	*
Judges	8	4.6900	14.1773	***
L x J	24	0.4667	1.4107	ns
Error	108	0.3308		
Total	143			
Moisture content				
Level of WHEAPRO (L)	3	1.6423	6.7717	***
Linear effect (l)		4.8028	19.8036	***
Judges	8	3.2492	13.3976	***
L x J	24	0.6894	2.8427	***
Error	108	0.2425		
Total	143			
Texture				
Level of WHEAPRO (L)	3	1.0457	5.0657	**
Linear effect (l)		3.0024	14.5440	***
Judges	8	2.3681	11.4715	***
L x J	24	0.4868	2.3580	**
Error	108	0.2064		
Total	143			

Table 21. (concl.)

Source	D/F	MS	F-value	Sig.[a]
Flavor				
Level of WHEAPRO (L)	3	4.0802	25.5348	***
Linear effect (l)		11.2799	70.5914	***
Judges	8	4.3465	27.2012	***
L x J	24	1.4082	8.8125	***
Error	108	0.1598		
Total	143			

[a]***, $P < 0.001$
**, $P < 0.01$
*, $P < 0.05$
ns, not significant.

EFFECTS OF VARYING PROPORTIONS OF WHEAT PROTEIN CONCENTRATE ON THE QUALITY OF CHAPATIS

by

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The effects on the quality of chapatis, when substituting 0, 10, 20 and 50% wheat protein concentrate (WPC) for part of the whole wheat flour, were investigated and compared. The chapatis, prepared from an Indian recipe, were evaluated objectively and subjectively, using a randomized balanced incomplete block design with 3 replications of each treatment.

The cooking loss increased as the percentage of WPC increased, but not always significantly. Both the percentage total moisture and the pH of the dough decreased as the percentage of WPC increased. The values for percentage total moisture of chapatis containing 50% WPC were significantly less than for each of the other levels of WPC; whereas the differences in values for pH were significant in all cases. The differences in reflectance (Rd) values of the chapatis attributable to WPC were significant except between the 10 and 20% levels. The degree of redness (a/b) values varied between levels, but only the value for chapatis with 50% WPC was significantly higher than that for each of the others. The only significant difference in volumes noted overall was between treatments with 0 and 50% WPC. The cooking loss was highest and the percentage total moisture lowest for the 50% level of WPC.

The average appearance, tenderness, moisture content and texture scores all decreased as the percentage of WPC increased. The color scores varied with the treatments but the differences were not always significant. There were significant differences noted in flavor scores except between the 0 and 10%. For the most part, when 50% WPC was substituted for an equal weight of whole wheat flour, the chapatis were scored significantly lower than those containing each of the other 3 levels and, generally, were not well received. Overall, there was a significant linear response to changes in level of WPC for all palatability factors.