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## Nutrient Level in Saudi Arabia Wheat Flour

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NUTRIENT LEVEL IN SAUDI ARABIA  
WHEAT FLOUR  
BY  
ABDULRHMAN AL-KHALIFA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF  
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IN  
FOOD SCIENCE AND NUTRITION

UNIVERSITY OF RHODE ISLAND

1982

MASTER OF SCIENCE THESIS

OF

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UNIVERSITY OF RHODE ISLAND

1982

## ABSTRACT

The chemical composition and protein quality of four varieties of wheat flour grown in Saudi Arabia (Rice Mexi-Pak, Red Mexi-Pak, Lugemi, and Moaeah), and one type of home bread (Korsan) made from Moaeah were evaluated. Analysis performed included proximate analysis, thiamine, riboflavin, iron, amino acid composition and protein efficiency ratio (PER). Protein and iron were higher in Moaeah and Lugemi. The protein quality assessed by PER was highest for Rice Mexi-Pak and lowest for Korsan, the cooked product. Chemical scores based on the essential amino acid content of the proteins were calculated; lysine and/or methionine was the limiting amino acid in the varieties of wheat studied.

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## TABLE OF CONTENTS

	PAGE
LIST OF TABLES . . . . .	v
LIST OF FIGURES . . . . .	vi
MANUSCRIPT - NUTRIENT LEVEL IN SAUDI ARABIA	
WHEAT FLOUR	
ABSTRACT . . . . .	1
INTRODUCTION . . . . .	2
MATERIALS AND METHODS . . . . .	5
RESULTS AND DISCUSSION . . . . .	11
REFERENCES . . . . .	25
APPENDICES:	
A. LITERATURE REVIEW . . . . .	28
B. BIBLIOGRAPHY OF THE COMPLETE THESIS . . . . .	39

LIST OF TABLES

TABLE		PAGE
1	Proximate Analysis of Wheat Flour. . . . .	12
2	Vitamin and Iron Content of Wheat Flour. . .	14
3	Amino Acid Composition of Different Varieties of Wheat . . . . .	16
4	Comparison of Essential Amino Acid Composition of Wheat and Egg . . . . .	18
5	Essential Amino Acid in Various Wheat Protein Expressed as Percentage of Whole Egg Protein. . . . .	19
6	Food Intake, Protein Intake, Gain in Weight, and PER of Different Varieties of Wheat Compared to Casein . . . . .	22

LIST OF FIGURES

FIGURE		PAGE
1	Average weight of ten rats fed (Rice Mexi-Pak, Red Mexi-Pak, Lugemi, Moaeah, Korsan, and Casin) for 28 days. . . . .	20
2	Weekly gains of ten rats fed (Rice Mexi-Pak, Red Mexi-Pak, Lugemi, Moaeah, Korsan, and Casin) for 28 days. . . . .	21



## PREFACE

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**MANUSCRIPT**

**NUTRIENT LEVEL IN SAUDI ARABIA**

**WHEAT FLOUR**

The nutrient content of wheat flour is an important factor in determining the nutritional value of wheat-based products. This paper reports the results of a survey of the nutrient content of wheat flour in Saudi Arabia. The survey was conducted in 1985 and 1986, and involved the analysis of 100 samples of wheat flour from 10 different regions. The results show that the nutrient content of wheat flour in Saudi Arabia is generally low, and that there is a significant variation in the nutrient content of wheat flour from different regions. The results also show that the nutrient content of wheat flour in Saudi Arabia is generally lower than that of wheat flour in other countries. The reasons for this are discussed in the paper.

## NUTRIENT LEVEL IN SAUDI ARABIA

## WHEAT FLOUR

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## ABSTRACT

The chemical composition and protein quality of four varieties of wheat flour grown in Saudi Arabia (Rice Mexi-Pak, Red Mexi-Pak, Lugemi, and Moaeah), and one type of home bread (Korsan), made from Moaeah were evaluated; analysis performed included proximate analysis, thiamine, riboflavin, and iron, amino acid composition and protein efficiency ratio (PER). Protein and iron were higher in Moaeah and Lugemi. The protein quality assessed by PER was highest for RiceMexi-Pak and lowest for Korsan, the cooked product. Chemical scores based on the essential amino acid content of the protein were calculated; lysine and/or methionine was the limiting amino acid in the varieties of wheat studied.

## INTRODUCTION

The world's most widely cultivated food plant, wheat, supplies more nutrients (calories, protein, and certain vitamins and minerals) for human nutrition than does any other source of food. Flour and cereal products provide 19% of the calories, 17% of the protein, and 35% of the carbohydrate available for civilian consumption in the United States diet (Marston and Friend, 1976), while in some developing countries cereals contribute up to 75% of the calories and 90% of the protein (Pomeranz, 1971). Some of these nutrients are consumed directly; those in animal feed derived from wheat are consumed indirectly. The quantity of wheat-based nutrients available for direct human consumption in various geographic regions of the world is best determined from the nutrient composition of the wheat flour used in the particular area.

Saudi Arabia is one of the countries in which wheat flour makes up the major portion of the diet. National consumption is about 700 thousand tons yearly. In past years about 95% of the wheat consumed was imported, but in 1978 the government changed the agriculture policy to encourage farmers to grow new varieties of wheat (Rice and Red Mexi-Pak) along with the old varieties such as Lugemi and Moaeah, thus reducing the import from outside. Approximately 60% of the wheat consumed is now from local production (Alyamamah, 1982).

Several experiments have been conducted in past years to evaluate the nutritional value of wheat flour. Hussein et al. (1979) determined the amino acid composition and protein quality of wheat flour. They concluded that lysine was the first limiting amino acid in all cases. Sikka et al. (1975) analyzed the mill fractions of whole wheat flour, bran, white flour and resultant atta. The protein quality index based on protein efficiency ratio and net protein retention at the 10% protein level was found to be highest in resultant atta, followed by bran, whole wheat flour, and white flour. The chemical score based on the essential amino acid content of egg protein and on the FAO provisional pattern indicated the limiting amino acids in different fractions. In resultant atta and bran, methionine and isoleucine were limiting, whereas in whole wheat and white flour, lysine, threonine and methionine were limited. Knight and Okoro (1980) showed that toasting affected the amino acid composition and protein of wheat flour and with increasing toasting temperature, destruction of some essential amino acid increased, and protein utilization decreased.

Ranum et al. (1980) reported the nutrient levels of internationally milled wheat flour. They concluded that the nutritional quality of large proportions of flour produced throughout the world is lower than that of wheat as a result of milling process. Davis et al. (1981)

evaluated 406 samples of flour, representing 231 varieties of wheat, grown in different years and in 49 locations for proximate and vitamin composition. They found significant differences in their composition by year, variety, and growing location.

Since there was no study of nutrient value for the old or new varieties of wheat flour in Saudi Arabia, the present study evaluated four different varieties of flour, two of the old varieties (Lugemi and Moaeah), and two new varieties (Rice and Red Mexi-Pak). In addition one type of home bread (Korsan), a flat circular loaf composed of one thin layer, was made from Moaeah and evaluated for nutrient value.

## MATERIALS AND METHODS

### 1. Sampling

The samples were collected from Al-Shenanah, Quasseam, Saudi Arabia. Four different varieties were chosen; namely, Lugemi, Moaeah, Red Mexi-Pak, and Rice Mexi-Pak. The samples were shipped to the United States, ground at the University of Rhode Island, and stored in plastic bags at 10°C.

Korsan. - Korsan, a local bread, was made from Moaeah variety. The bread contained flour, water, a small amount of salt and oil and was baked on a hot plate for 5-6 minutes. The bread was allowed to air dry and was then ground in a blender.

### 2. Proximate Analysis

#### 2:1 Moisture content:

The moisture content of each sample was determined by heating at 95-100°C in an oven until a constant weight was achieved.

#### 2:2 Determination of crude fat:

The crude fat was determined using Association of Official Analytical Chemists method (AOAC, 1979). Fat was extracted with petroleum ether. The ether extract was dried and weight gain of the extraction flask determined. This weight gain was reported as crude fat.



### 2:3 Determination of crude protein:

The improved Kjeldahl method described by the Association of Official Analytical Chemists (AOAC, 1979) was employed to determine the nitrogen content of each sample. This method includes three procedures; i.e., digestion with sulfuric acid, distillation of the digested solution with 45% NaOH, and titration of the excess acid in the distillate. The nitrogen content was then converted to crude protein by multiplying by 5.7.

### 2:4 Ash:

The ash content was determined by ignition of the sample in a muffle furnace at 600°C for two hours.

### 2:5 Crude fiber:

The crude fiber was determined using the Association of Official Analytical Chemists method (AOAC, 1979). Samples were digested with 1.25%  $H_2SO_4$  and 1.75% NaOH under the specified conditions.

## 3. Minerals:

### 3:1 Iron:

Oven dried ground sample was placed in a 150 ml beaker, ashed in muffle furnace at 500°C overnight, and then dissolved in concentrated HCl, and boiled to evaporate the solution nearly to dryness. The residue was dissolved in 2N hydrochloric acid, filtered and diluted to 100 ml in volumetric flask. The concentration of the iron was measured with a Perkin Elmer Atomic Absorption



Spectrophotometer Model 403. A standard addition curve was used for calculation of the iron.

#### 4. Vitamins:

##### 4:1 Thiamine:

The recommended Thiochrome method of the American Association of Cereal Chemists was used (AACC, 1976). Thiamine was extracted with sulfuric acid in a boiling water bath for 10 min. After cooling, the thiamine was hydrolyzed with 2%  $\alpha$ -amylase solution at 37-40°C for four hours. The enzyme hydrolysate was diluted to 100 ml and filtered through filter paper (Whatman No. 2). An aliquot of the extract was passed through an adsorption column packed with activated Decalso. The column was washed with three portions of hot water to ensure proper distribution of thiamine on the column. The column was eluted with boiling 25% potassium chloride solution. This eluate contained all the thiamine. The solution was then oxidized using potassium ferricyanide (3 ml of 1% potassium ferricyanide in 100 ml of 15% sodium hydroxide) and the thiochrome formed was extracted with isobutanol. Fluorescence of oxidized thiamine (thiochrome) was measured in a Farrand fluorometer.

##### 4:2 Riboflavin:

The American Association of Cereal Chemists method (AACC, 1976) was used to determine the riboflavin content of the wheat flour. Riboflavin was extracted with

sulfuric acid by autoclaving the mixture of 15 lb pressure for 30 minutes. Five ml of 2.5 M sodium acetate was then added and after one hour the mixture was diluted to 100 ml and filtrated through filter paper (Whatman No. 2). The solution then was oxidized by 4% potassium permanganate and 3% hydrogen peroxide. Riboflavin was measured in a Farrand fluorometer.

## 5. Protein Quality:

### 5:1 Diets:

Five experimental diets and a casein control were prepared according to the AOAC official method for biological evaluation of protein quality. All diets contained 10% protein, 8% fat, 5% mineral, 1% vitamin mixture (Nutritional Biochemical ICN), 1.76% fiber, 7.35% moisture, and 77% carbohydrate. Proximate analysis values of wheat and casein were used to calculate the diets. Diets were made up to desired composition by addition of corn oil, salt mix (Jones Foster), alpha cell (General Biochemical Co.) and carbohydrate (50% sucrose and 50% cornstarch), as needed.

### 5:2 Protein efficiency ratio (PER):

The bioassay procedures outlined in the official method (AOAC, 1975) for conducting the biological evaluation of protein quality were followed. Male rats, weighing 35-45g, 21 days of age, were obtained from Charles River Breeding Labs. Upon receipt, the animals

were housed in individual cages in a room where temperature (72-75°F) and lighting (12 hours light and 12 hours dark) were controlled. For the first four days rats were fed rat chow, on the fifth day assay groups were assembled in lots of 10 rats in random manner, so that the weight differential was less than 5 g. Throughout the 28-day test period, feed and water were available ad libitum. Individual food consumption records and weight gain were determined two times per week. Upon conclusion of 28 day feeding studies, PER values were calculated for each group as follows:

$$\text{protein efficiency ratio (PER)} = \frac{\text{body weight gain (g)}}{\text{protein consumed (g)}}$$

6:1 Amino acid:

Amino acid content was determined by Hebert V. Shuster, Inc., Quincy Research Park, 5 Hayward Street, Quincy Mass. 02171. Samples were analyzed by Kontron Liqumat III Analyzer Model 100.

6:2 Tryptophan:

The method described by Miller (1967) and Spies et al. (1949) was employed to determine the tryptophan content. The sample was digested with barium hydroxide in an autoclave at 15 lb pressure for 7 hours. After cooling, the alkaline solution was titrated with 6N hydrochloric acid. The neutralized solution was transferred with washing to a centrifuge tube. It was then mixed with

40 ml of a solution of 175 gm anhydrous sodium sulfate per liter and centrifuged at 2700 x g for 10 minutes. The supernatant was decanted and made up to 100 ml in a volumetric flask. Two ml of hydrolysate were reacted with p-dimethylaminobenzaldehyde (0.5 gm in 100 ml concentrated hydrochloric acid) for 20 minutes, followed by an addition of sodium nitrate (0.2 g/100 ml H<sub>2</sub>O to yield a characteristic blue color. The intensity of color was measured with a Spectronic 20 at 590 nm wave length. The standard comparison curve was prepared by plotting concentration versus optical density.

#### 6:3 Chemical score:

Calculation of chemical score was based on the essential amino acid pattern of egg as reference protein. The method of Mitchell and Block (1946) was adopted to calculate chemical scores. The ratio of the quantity of each essential amino acid in wheat protein compared to the quantity of the respective amino acid in whole egg protein was computed and stated as a percentage. The lowest of these percentages is the chemical score.

#### 7. Statistical Analysis:

Data was analyzed by analysis of variance (ANOV) and Duncan's New Multiple Range Test.

## RESULTS AND DISCUSSION

## 1. Proximate Compositions:

The proximate composition of the various wheats is shown in Table 1.

Moisture:

Moisture values had an overall mean of 7.4% and ranged from 9.6% for Rice Mexi-Pak to 6.92% for Moaeah. Difference in moisture content could have been due to variety, type of storage or time of collection. Moisture content of Korsan was lower, probably indicating a loss of moisture in cooking.

Ash:

Ash content ranged from 1.44% for Red Mexi-Pak to 1.93% for Moaeah. Ash content for Korsan, the cooked product, appeared higher than that in Moaeah which might be due to ingredients added to the Korsan.

In the U.S., Holland and Ritchie (1941) reported a range of 1.72-2.4% ash in wheat; Keagy et al. (1980) reported 1.84% for hard and 1.87% for soft wheats; Kent (1975) reported 1.8% ash in wheat; and Davis et al. (1981) reported 1.17-2.96% ash in wheat. Thus, the overall means of Arabian wheat was similar to those reported by Davis et al (1981), and Keagy et al. (1980).

Crude Fiber:

Crude fiber values had an overall mean of 2.3 except for Moaeah which was 2.62%.



TABLE 1. Proximate Analysis of Wheat Flour

	Moisture % <sup>(1)</sup>	Ash %	Crude Fat %	Crude Protein % <sup>(2)</sup>	Fiber %
Rice Mexi-Pak	9.6 ± .090 <sup>a(3)</sup>	1.62 ± .025 <sup>a</sup>	1.88 ± .019 <sup>a</sup>	12.2 ± .135 <sup>a</sup>	2.33 ± .012 <sup>a</sup>
Red Mexi-Pak	9.24 ± .102 <sup>b</sup>	1.44 ± .030 <sup>b</sup>	1.87 ± .037 <sup>a</sup>	13.0 ± .136 <sup>b</sup>	2.30 ± .015 <sup>a</sup>
Lugemi	6.98 ± .066 <sup>c</sup>	1.82 ± .025 <sup>c</sup>	2.18 ± .058 <sup>b</sup>	16.2 ± .141 <sup>c</sup>	2.35 ± .031 <sup>a</sup>
Moaeah	6.92 ± .058 <sup>c</sup>	1.93 ± .027 <sup>d</sup>	1.95 ± .022 <sup>a</sup>	16.8 ± .063 <sup>d</sup>	2.62 ± .058 <sup>b</sup>
Korsan (Home Bread)	5.0 ± .075	2.6 ± .04	4.40 ± .082	14.7 ± .093	2.50 ± .06

<sup>1</sup> All values expressed as percent wet weight

<sup>2</sup> % N x 5.7

<sup>3</sup> Data presented as mean ± Standard error for five replicates, for each parameter means with different super scripts are significantly different (p = 0.05)

### Protein:

Protein content ranged from 12.2% (Rice Mexi-Pak) to 16.8% (Moaeah). Differences in protein content may be due to variety, type of soil and available soil nitrogen. Rice and Red Mexi-Pak had 12.2% and 13.0% protein, while Lugemi and Moaeah had 16.2% and 16.8%, respectively. This range of values is similar to that reported by Kulp et al. (1980) and holland et al. (1941). For Korsan the protein content appeared to be lower than Moaeah. These losses might happen during the baking.

### Crude fat:

Fat content ranged from 1.87% for Red Mexi-Pak to 2.18% for Lugemi. For Korsan, the fat content was higher than Moaeah because of use of oil in preparation of the bread. The range of values is similar to that reported by Pomeranz et al. (1966).

## 2. Vitamin Content: Thiamine and Riboflavin:

### Thimaine:

The mean thiamine content for all wheat flours was .18 mg/100 g of flour. Thiamine content of Lugemi (.21 mg/100 g) was the highest, followed by Moaeah (.2 mg/100 g); Rice Mexi-Pak (.18 mg/100 g) and Red Mexi-Pak and Korsan (.16 mg/100 g) (Table 2). Keagy et al. (1980) reported the range of thiamine .153 mg/100 g to .214 mg/100 g in wheat flour in the United States.

TABLE 2. Vitamin and Iron Content of Wheat Flour<sup>(1)</sup>

	Rice Mexi-Pak	Red Mexi-Pak
Thiamine (mg/100 gm)	.18 (.176-.183) <sup>(2)</sup>	.16 (.16-.16)
Riboflavin (mg/100 gm)	.12 (.118-.123)	.14 (.138-.142)
Iron (mg/100 gm)	1.60 (1.59-1.62)	1.40 (1.40-1.40)

	Lugemi	Moaeah
Thiamine (mg/100 gm)	.21 (.20-.216)	.20 (.20-.20)
Riboflavin (mg/100 gm)	.13 (.13-.13)	.13 (.127-.132)
Iron (mg/100 gm)	2.20 (2.15-2.24)	2.50 (2.50-2.50)

	Korsan
Thiamine (mg/100 gm)	.16 (.154-.165)
Riboflavin (mg/100 gm)	.12 (.12-.12)
Iron (mg/100 gm)	2.80 (2.77-2.82)

<sup>1</sup> Based on wet weight

<sup>2</sup> Mean of 3 determinations, range of values given in parenthesis.



### Riboflavin:

The mean riboflavin content of all four varieties was .127 mg/100 g. The range was from .12 mg/100 g (Rice Mexi-Pak, Korsan) to .14 mg/100 g (Red Mexi-Pak). Davis et al. (1981) have reported a riboflavin content in ranges of .1 mg/100 g to .17 mg/100 g, and Hamad et al. (1979) has reported a mean .14 mg/100 g.

### 3. Mienrals:

#### Iron:

Table 2 shows the iron content of the wheat flour; Moaeah contained higher iron than other varieties. A variation in iron content of different varieties of wheat has been reported by Pomeranz et al. (1982).

#### Amino acids:

The results of analysis for amino acids are given in Table 3. All results have been expressed as amino acid content of g/16 g of N. In agreement with other studies in this field, it is clear that wheat samples of widely differing protein content and type resemble one another quite closely in amino acid composition. The amino acid content agrees very well with the results reported by Sikka et al. (1975) and Simmonds (1968).

Threonine and tryptophan did tend to be lower in samples of higher nitrogen (Moaeah, Lugemi), lysine which was lower only in Lugemi; other changes in amino acid composition seemed minor. Comparing home bread (Korsan)

TABLE 3. Amino Acid Composition of Different Varieties of Wheat (g/16 g of N)

AMINO ACID	Rice Mex.	Red Mex.	Lugemi	Moaeah	Korsan
Aspartic Acid	6.61	5.81	6.52	6.04	6.01
Threonine	3.75	3.40	3.18	3.16	3.18
Serine	5.47	5.27	4.92	4.84	4.98
Glutamic Acid	34.02	33.25	32.41	33.87	34.32
Glycine	5.09	5.51	4.94	5.54	5.78
Alanine	4.53	4.80	4.65	4.55	4.75
Valine	5.67	6.12	5.94	5.76	5.81
Methionine	1.45	1.28	1.3	1.22	1.33
Isoleucine	4.29	4.55	4.57	4.38	4.27
Leucine	7.94	8.94	8.78	8.52	8.74
Tyrosine	3.73	2.66	3.55	3.89	3.49
Phenylalanine	5.80	5.79	5.84	6.25	5.87
Lysine	3.36	3.34	3.18	3.32	2.92
Histidine	2.82	3.10	3.12	2.94	2.87
Arginine	5.48	6.18	6.54	5.71	5.68
Tryptophan	.96	.8	.75	.76	.77
Chemical Scores	43	40	41	38	37
Total Nitrogen	2.00	2.20	2.80	2.95	2.58

with Moaeah, there was no inhibitory or stimulatory effect in the content of amino acid in bread during baking, with the exception of lysine; there was a 12% decrease in lysine content in the bread after baking.

Chemical score was calculated from essential amino acid composition of the four wheat varieties and Korsan using eggs as the reference protein. The results are presented in Tables 4 and 5. It is observed from Tables 4 and 5 that chemical score values are highest for Rice Mexi-Pak, followed by Lugemi and Red Mexi-Pak, and then Moaeah and Korsan. The limiting amino acid in Rice Mexi-Pak and Korsan is lysine. In Red Mexi-Pak and Moaeah Methionine is limiting. Methionine and Lysine are limiting in Lugemi.

#### Protein Efficiency Ratio:

Figures I and II present the growth curve of rats during 28 days. In Figure I is shown the average weight of rats fed four varieties of wheat, home bread (Korsan) and a Casein as control. Figure II shows the average weekly gain.

Table 6 shows food intake, protein intake, mean values of gain in weight and PER for each group. The PER value for Rice Mexi-Pak was significantly higher than Red Mexi-Pak, Lugemi, Moaeah and Korsan. Red Mexi-Pak had the same PER value as Lugemi. Moaeah has a lower PER but the difference was not statistically different. All values

TABLE 4. Comparison of Essential Amino Acid Composition of Wheat and Egg

Amino Acids	Whole <sup>(1)</sup> Egg	Rice Mex.	Red Mex.	Lugemi	Moaeah	Korsan
Histidine	2.6	2.82	3.10	3.12	2.94	2.87
Lysine	7.8	3.36	3.34	3.18	3.32	2.92
Methionine	3.2	1.45	1.28	1.30	1.22	1.33
Phenylalanine	5.5	5.80	5.79	5.84	6.25	5.87
Tyrosine	3.8	3.73	2.66	3.55	3.89	3.49
Leucine	8.8	7.94	8.94	8.78	8.52	8.74
Isoleucine	5.9	4.29	4.55	4.57	4.38	4.27
Valine	7.1	5.67	6.21	5.94	5.36	5.81
Threonine	4.9	3.75	3.40	3.18	3.16	3.18
Tryptophan	1.4	.96	.8	.75	.76	.77
Total	51	39.77	40.48	40.21	40.20	39.25

<sup>1</sup> Albanese, New Methods of Nutritional Biochemistry.

TABLE 5. Essential Amino Acid in Various Wheat Proteins Expressed as Percentage of Whole Egg Protein

Amino Acid	Rice Mex.	Red Mex.	Lugemi	Moaeah	Korsan
Histidine	100	100	100	100	100
Lysine	<u>43</u>	43	<u>41</u>	42	<u>37</u>
Methionine	45	<u>40</u>	<u>41</u>	<u>38</u>	42
Phenylalanine	100	100	100	100	100
Tyrosine	98	70	93	100	92
Leucine	90	100	100	97	99
Isoleucine	73	77	77	74	72
Valine	80	86	84	81	82
Threonine	76	69	65	64	65
Tryptophan	69	57	55	55	55

<sup>1</sup> Values underlined are the chemical scores.

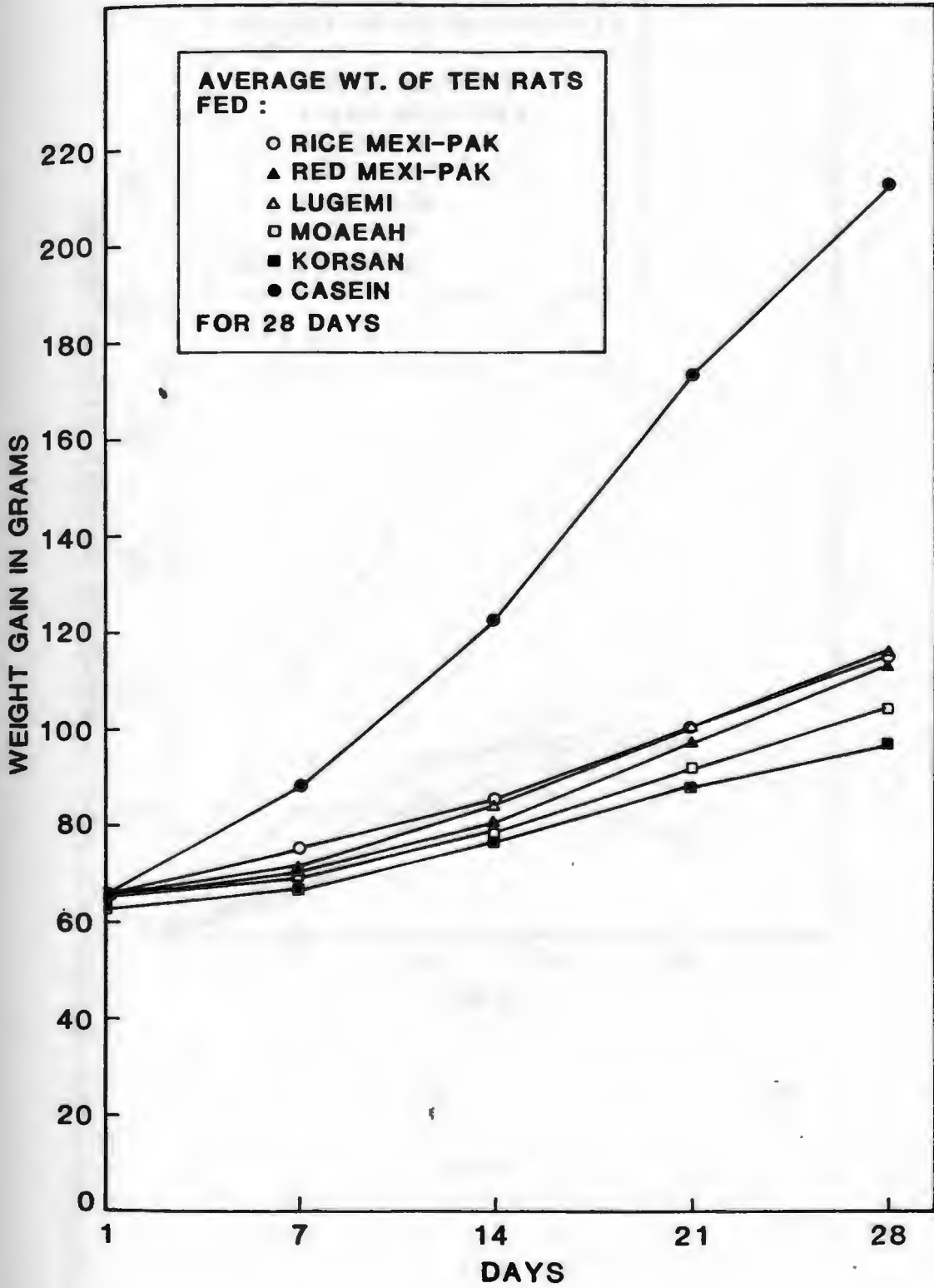


Figure 1

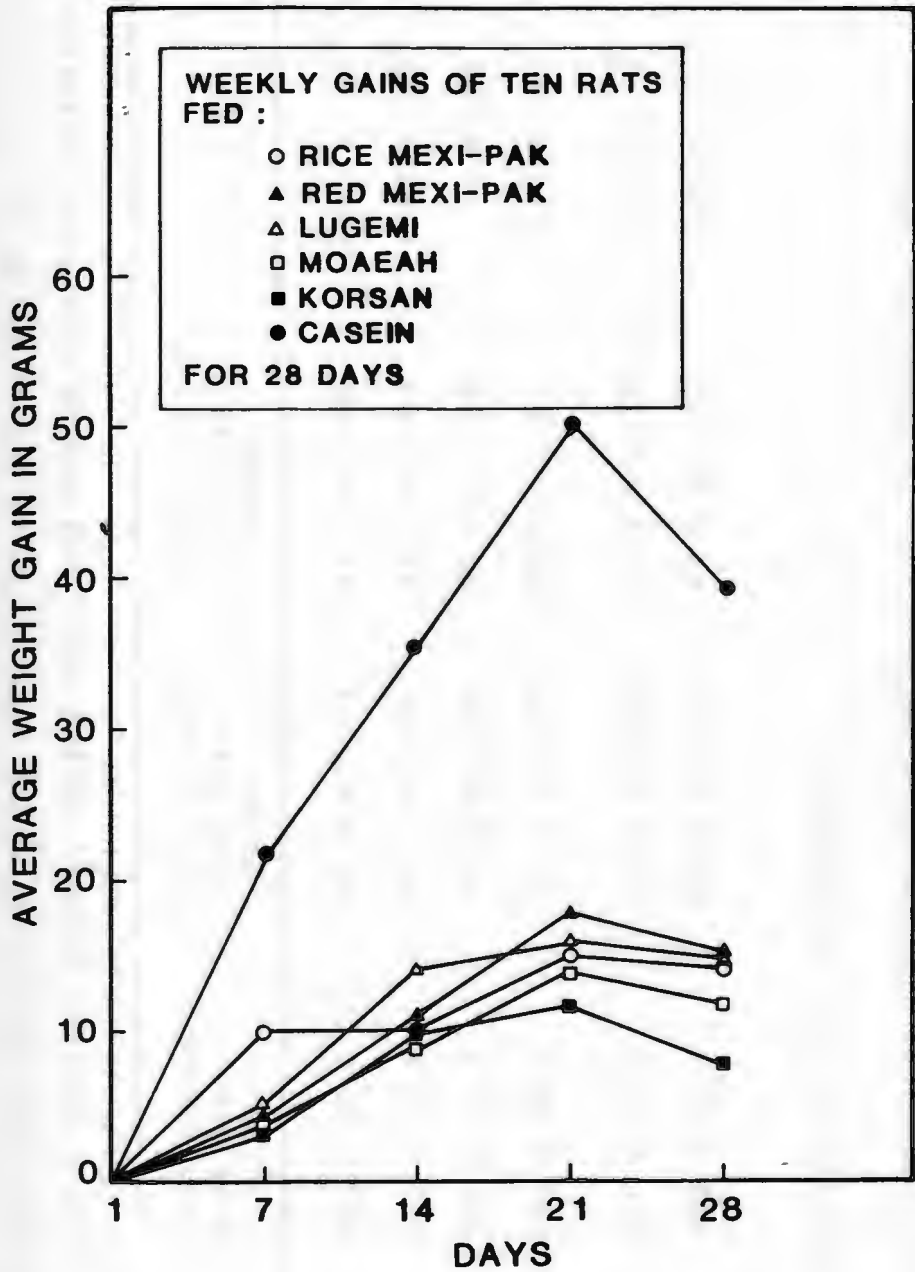


Figure 2



TABLE 6. Food Intake, Protein Intake, Weight Gain, and PER of Different Varieties of Wheat Compared to Casein.

Protein Source	Food Intake g/28 days animal	Mean Weight 5/28 days/ animal	Protein Intake g/28 days/ animal	PER
Rice Mexi-Pak	313 ± 20.2 <sup>(1)</sup>	49.0 ± 5.03	31.3 ± 2.02	1.56 ± .07 <sup>a(2)</sup>
Red Mexi-Pak	333 ± 10.2	47.1 ± 2.66	33.3 ± 1.03	1.40 ± .07 <sup>b</sup>
Lugemi	350 ± 11.3	44.2 ± 2.66	35.0 ± 1.05	1.40 ± .07 <sup>b</sup>
Moaeah	349 ± 10.9	42.3 ± 1.80	34.9 ± 1.12	1.20 ± .02 <sup>bc</sup>
Korsan (Home Bread	297 ± 17.8	33.3 ± 1.95	29.7 ± 1.78	1.12 ± .03 <sup>c</sup>
Casein	490 ± 13.0	146.6 ± 5.63	49.0 ± 1.30	3.00 ± .11 <sup>d</sup>

<sup>1</sup> Mean plus standard error for 10 animals.

<sup>1</sup> Values with different superscripts are significantly different (p = 0.05).



were within the average for wheat given by FAO (1.17-1.77).

The PER for Korsan was lower than Moaeah, but the difference was not statistically different. The lysine content of Korsan was lower than that of Maoeah, however that difference did not make a significant difference in the utilization of the protein by growing rats.

From the overall evidence presented, it appears obvious that the nutrient value of the old varieties (Lugemi and Moaeah) is similar to the new varieties (Rice and Red Mexi-Pak) supported by the government, except for iron and protein. Iron was higher in the old varieties than the new varieties. Wheat flour when consumed in large amount, provides a significant amount of iron; however, iron is poorly absorbed from wheat product and in the Saudian diet is provided from other sources such as meat and fish. Also, one of the new varieties, Rice Mexi-Pak has a significantly higher PER than the old varieties, however the other new variety, Red Mexi-Pak was not significantly different in quality from the old varieties. The differences in protein quality and quantity may not be of nutritional significance as the people of Saudi Arabia also consume protein from meat, fish and vegetables. The advantage of the new varieties are in their larger yield and increased resistance to disease. Therefore, it may be more beneficial to grow the new

varieties.

The composition of Saudi Arabian wheat flour was compared to values for wheat flour reported in the literature. Saudi Arabian wheat flour had a composition similar to that of wheat grown in the United States.

## REFERENCES

- Albanese, A.A. 1967. New Methods of Nutritional Biochemistry, Volume III, pp 130.
- Alyamamah Magazine (1982) No. 691, pp 18-22, Riyadh, Saudi Arabia.
- American Association of Cereal Chemists. 1976. Approved Methods of the AACC.
- Association of Official Analytical Chemists. 1979. Method of Analysis. Washington, D.C.
- Davis, K.R., Cain, R.F., Peters, L.J., Letournea, D., and McGinnis, J. 1981. Evaluation of the Nutrient Composition of Wheat, II. Cereal Chemistry v. 58, No. 2, pp 116-120.
- FAO/WHO Protein Requirements, Rome. FAO Nutrition Meeting Report Series No. 37, 1485.
- Hamad, A.M. and Fields, M.L. 1979. Nutritional and Sensory Evaluation of Bread and Corn Chips made from Fermented Wheat and Corn Meals. Fd. Sci. Technol. pp 17-18.
- Holland, R.B. and Ritchie, W.S. 1941. Trace Metals and Total Nutrient in Human and Cattle Food. Mass. Agric. Exp. Stn. Bull. 379.
- Hussein, L., Abbassy, M., Arafa, A. and Marcos, S.P. 1979. Evaluation of the Protein Quality of Wheat Grains and Eight Related Products by the Close Response Bioassay. Zeitschrift Fuer Ernaehrungswissenschaft, Vol. 18, pp 275-285.
- Knight, E.M. and Okoro, C. 1980. The Effect of Toasting on the Amino Acid Composition and Utilization of Protein from Unsupplemented and Soy Bean Supplemented White Bread. Federation Proceedings, v. 39 (3-II), pp 1115.
- Kulp, K., Ranum, P.M., P.M., Williams, P.C. and Yamazaki, O.T. 1980. Natural Levels of Nutrients in Commercially Milled Wheat Flours. I. Description of Samples and Proximate Analysis. Cereal Chem., v. S7(1), pp 54-58.
- Lorenz, K. and Lowew, R. 1977. Mineral Composition of U.S. and Canadian Wheat and Wheat Blends. J. Agric. Food Chem., Vol. 25, No. 4, pp 806-809.

Marston, R. and Friend, B. 1976. Nutritional Review. National Food Situation v, 15d, pp 25.

Miller, E.L. 1967. Determination of the Tryptophan Content of Feeding Stuffs with Particular Reference to Cereal. J. Sci. Fd. Agric. v. 18, pp 381-386.

Mitchell, H.H. and Block, R..S 1946. Some Relationship Between the amino acid contents of Proteins and Their Nutritive Values for the Rat. J. Biol. Chem., v. 163, pp 544-620.

Mitra, G.N. and Bas, N.B. 1971. Protein Quality of High Yielding Varieties of Rice, J. Agr. Food Chem. v. 19, pp 427-924.

Pomeranz, Y., Keman, E. and Lai, F.S. 1982. Minerals and Protein Content in Hard Red Winter Wheat. Cereal Chem. v. 5a (2), pp 139-142.

Ranum, F.F., Barrett, R.J., Loewe and Kulp, K. 1980. Nutrient Levels in Internationally Milled Wheat Flour. Cereal Chemistry, Vol. S7, pp 361-366.

Simmonds, D.H. 1962. Variations in the Amino Acid Composition of Australian Wheat and Flour. Cereal Chem. v. 39, pp 445.

Sikka, K.C., Johari, R.P., Duggal, S.K., Ahuja, V.P. and Austin, A. 1978. Comparative Nutritive Value and Amino Acid Content of Different Extractions of Wheat. Journal of Agricultural and Food Chemistry, Vol. 23, pp 24-26.

Spier, J.R. and Chambers, D.C. 1949. Chemical Determination of Tryptophan in Protein Analytical Chemistry. 27(10) pp 1249-1266.

Tabekhia, M.M. and Mohammed, M.S. 1971. Effect of Processing and Cooking Operation on Thiamine, Riboflavin, and Nicotinic Acid Content of Some Egyptian National Food Wheat Flour, Bread and Rice. Alexandria Journal of Agricultural Research, Vol. 19, pp 274-284.

U.S. Department of Agriculture Survey, cited in Pomeranz, Y. Wheat Chemistry and Technology. American Association of Cereal Chemists, St. Paul, 1971, p 727.





## LITERATURE REVIEW

The world's most widely cultivated food plant, wheat, supplies more nutrients (calories, protein and certain vitamins and minerals) for the human nutrition than does any other single source of food. Some of these nutrients are consumed directly; those in animal feed derived from wheat are consumed indirectly. The quantity of wheat-based nutrients available for direct human consumption in various geographic regions of the world is best determined from the nutrient composition of the wheat flour used in the particular area. Published data for wheat, although more readily available, are less accurate because they do not reflect nutrient losses from milling and manufacturing. In view of the wide acceptance of modern milling technology even in the developing countries, these losses are not inconsequential.

Protein and protein quality:

Cereals are regarded primarily as energy food; however, they are also important sources of protein. Protein is one of the most difficult nutrients to obtain because foods high in protein are usually the most expensive food stuffs. It has been recognized that the human body requires protein in sufficient amount and of specific amino acid composition. Although the quantity of protein in wheat can vary from 7 to 22%, the average value is higher than for other cereal grains. However, other protein

sources such as meat are higher in protein content.

The quality of wheat protein is poor relative to other protein sources such as meat, fish, and soybeans. Protein quality and quantity are affected by several factors including milling procedures, cooking, the variety of wheat, the location and growing conditions.

Miladi, et al (1972) determined total amino acid content, digestibility and relative nutritive value (RNV) of the protein in mill fractions obtained by standard milling procedures from a single sample of wheat (germ, wheat protein concentrate, red dog, bran, shorts, patent flour, and clear flour). RNV of these products correlated highly with lysine content of proteins, and an even higher correlation was obtained when corrections for digestibility were applied. Lysine supplementation improved nutritional value in all products with the exception of germ and wheat protein concentrate. A chemical score based upon essential amino acid content of egg protein did not appear to identify the most limiting amino acid in several of the proteins.

Sikka (1975) studied the mill fractions obtained by standard milling from a single wheat sample. Whole wheat flour, bran, white flour (maida) and resultant atta were analyzed for their nutritive value. The protein quality index based on protein efficiency ratio and net protein retention at a 10% protein level was found to be

highest in resultant atta, followed by bran, whole wheat flour, and white flour. A chemical score based on the essential amino acid content of egg protein and an FAO provisional pattern of milk protein indicated the limiting amino acids in the different fractions. In resultant atta and bran, the limiting amino acids were methionine and isoleucine, whereas in whole wheat and white flour, lysine, threonine and methionine were limiting.

Orth (1976) analyzed the amino acid composition and protein digestibility of bread flour and individual reaction streams obtained by milling a semi-hard Australian bread wheat. An increase in the proportion of albumin plus globulin and decreases in the proportions of gliadin and soluble glutenin plus residue were observed for flours obtained from the end reduction streams. Amino acid analysis of these streams showed an increase in those amino acids characteristic of the "metabolically active" protein (albumins and globulins) and/or "gluten-forming" proteins (gliadins and glutenins). A most important change was in lysine content which increased from 1.50 gm/16 gm nitrogen in the bread flour to 2.36 gm/16 gm nitrogen in the reduction flour. In vitro protein digestibilities showed a slight decrease for the end reduction streams. The bread flour had a protein digestibility of 90.6% compared with 88.8% for the reduction flour. The end reduction streams appear to have a nutritional advantage over



the bread flour and earlier reduction streams because of the former's higher protein contents, higher lysine contents and similar protein digestibilities.

Nelson (1977), studied the flour protein of 8 selected streams from a pilot mill. The protein content of flour streams from 4 varieties varied from 11 to 25% with the first and fourth mid-streams being the lowest and the fifth bread flour stream the highest. Yield of wet and dry gluten from the protein of flour streams was rather constant even though the protein contents of streams were markedly different. The protein fractions of two varieties were quantitatively determined by gel filtration. The relative amounts of the flour protein as the protein fractions glutenin, gliadin, albumin, and nonprotein nitrogen were a little different between flour streams, but the differences were not the same between the two varieties tested. Amino acid scores calculated from complete amino acid analysis indicated that lysine and threonine were nutritionally the first and second limiting amino acids, respectively, and the nutritional quality of the protein in different streams varies little.

Awadalla (1974), analyzed the nutritional value of wheat, whole millet (*Panicum miliacum*), decorticated millet and 80.20 wheat:millet mixtures. Results showed that millet had a much higher caloric value than wheat,

but a lower protein content. The protein quality of mixtures (expressed as mg essential amino acids/G total N) was higher than that of wheat alone. The net protein utilization of the mixtures was slightly lower than that of wheat. Lysine was the first limiting amino acid in both millet and wheat; its concentration was similar in wheat and whole millet, but lower in decorticated millet. It is concluded that substitution of 20% millet flour in wheat flour would have no significant adverse nutritional effects.

El-Ghamry (1975), reported that addition of 0.3% lysine to Tunisian wheat flour protein improved both quality and quantity of utilizable protein. Qualitatively, using egg protein as reference, 69.3% improvement was obtained. By using the latest FAO/WHO suggested amino acid scoring pattern, 75% amelioration was obtained. Quantitatively, the percent utilizable wheat protein increased from 3.0 to 5.4 after lysine fortification. Hussein et al, 1974 determined the amino acid composition and protein quality for whole grains of a soft winter wheat and for the following products: (1) belila (cooked grains) and (2) baladi bread. Lysine was the first limiting amino acid in all cases.

Knight and Okoro (1980) showed that toasting affected the amino acid composition and utilization of protein from unsupplemented wheat flour, and with increasing toast-

ing temperature, destruction of some essential amino acid increased. Rat feeding tests showed the protein utilization decreased with increasing toasting temperature.

Protein and amino acid profiles of normal and yellow-berry bread wheat have been examined (Waines et al., 1978). The investigators concluded that values for nitrogen concentration in yellow-berry kernels of bread wheat varied from 91.6 to 72.9% of those for normal kernels. Also, values for total amino acid concentration in whole wheat flour of yellow-berry kernels were less than those of whole wheat flour of normal kernels. Lysine and threonine were higher in yellow-berry kernels than in normal kernels. Glutamic acid was lower in yellow-berry kernels than in normal kernels.

Abrol et al. (1971), reported that the enhanced protein content of wheat observed following increased fertilizer application is mainly accounted for by an increase in gluten content. Levels of glutamic acid, phenylalanine, proline, and leucine increased at high fertilizer levels, while the reverse was true for lysine, valine, threonine, isoleucine and tryosine.

Haber et al. (1976) had studied the amino acid composition of hard red winter wheat and tritival. They found that the amino acid composition of tritival flour showed higher lysine levels than hard red winter wheat flour.

### Vitamins and Minerals:

Wheat contains a significant amount of vitamins, but processing changes and reduces their content. Wheat also contains a variety of minerals, usually in small quantity. Wheat, when consumed in large quantities, has been considered an important source of thiamine, riboflavin, and iron in human diets.

Keagy et al. (1980) have reported that milling variables greatly influenced the vitamin content of the flour. As done by correlations with flour ash content, pyridoxine gave the highest correlation, followed by thiamin, folacin and niacin. Riboflavin and pantothenic acid showed little or no correlation. Finally, hearth flours had the highest vitamin content, followed by baker's bread, cookie, family and cake flours.

The effect of processing and cooking operations on thiamine, riboflavin and nicotonic acid content of Egyptian wheat flour and bread have been studied (Tabekhia and Mohamed, 1971). The results indicated that whole wheat flour contained a higher level of nicotinic acid than rice and bread, while thiamine and riboflavin were present in relatively lower concentration. Toasting of Baladi bread for 10 minutes after baking reduced thiamine by 36% while riboflavin and nicotinic acid remained unchanged.

Koivistoinen (1974), reported the mineral element contents (Fe, Cu, Mn, Mg, Na, K, Ca, and P) of cereal



flours and flakes from 198 sampels of three kinds of wheat flour (ash contents of 0.47, 0.57, and 1.28%, respectively); rye flour (ash 1.77%), barley flakes (ash 1.45%) and oat flakes (ash 2.04%). When all the cereal products, in pairs, were tested for the significance of differences (P less than 0.025) in the mineral element contents it was found that the two low-ash wheat flours were similar in Fe, Cu, Mn, Zn, Na and Ca contents. Rye flour, barley flakes, and oat flakes were similar in Fe and Cu contents. The proportion of each mineral element in the ash was generally of the same order of magnitude in all the cereal products. The total amounts of the nine mineral elements made up 38-50% of the total ash for the cereal products. P (average 18.4%), K (average 16.7%), Mg (average 6.16%), and Ca (2.9%) had the highest proportions in ash.

Lorenz (1980), reported the minerals components (Fe, Mg, Cu, Zn) of the samples of wheat flour (baker's bread, family) from mills throughout the U.S. and Canada as determined by different laboratories. Significant differences were found between laboratories for each of the analyzed elements, mainly because of differences in the extractions procedures. The level of Ca in flour depended mainly on the Ca content of the wheat and was little affected by milling variables. Levels of Fe, Mg and Zn in flour followed a different pattern from that of Ca and depended more on milling variables. These

elements were highly correlated with flour, ash and protein content and showed significant differences between flour types. The differences could be explained by Ca having a distribution within the wheat kernel different from that of Fe, Mg and Zn.

Brennan (1971), reported recovery of protein, thiamine, riboflavin and niacin during milling of six wheat varieties, grown at two localities. Nutrients were determined in both unmilled and milled samples. Varieties differed considerably in color, yield and protein, thiamine and niacin contents; riboflavin levels were relatively constant. Hard wheats gave higher yields and better recovery of riboflavin and niacin than soft wheats, but thiamine did not differ significantly. Neither flour color nor protein content was associated with vitamin levels. Wheat grown at one locality contained less protein and more riboflavin and niacin than that at the other locality; these differences also occurred in flours, but at lower levels. Thiamine content of wheat had a relationship to levels of flour. Effect of extraction rate on composition, color and baking quality of flour from five wheat varieties was determined. Values for flour color, loaf volume, crumb color, loaf score, and protein, thiamine, riboflavin, and niacin are tabulated for yields of 61, 69, 71, and 75%. Loaf quality declined sharply at higher extraction rates and color grades, although protein



and vitamin contents were higher. All wheats showed a steady decline of thiamine content in particular, and of other constituents to a lesser extent, as extraction rates decreased.

Ranum (1980), reported results of analysis of 95 samples of commercially milled wheat flour, produced in 30 countries, for contents of ash and for protein, vitamins B<sub>1</sub> and B<sub>2</sub>, niacin, Fe, Ca, Zn and Mg. They concluded that the nutritional quality of large proportions of flour produced through the world is lower than that of wheat as a result of the milling process.

From the above, it is apparent that the protein quantity and quality, vitamins, minerals, biological and chemical composition of wheat varies widely, depending on environment, soil, variety and type of extraction and processing.

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APPENDIX B

BIBLIOGRAPHY OF THE COMPLETE THESIS

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- Abrol, Y.P., Uprety, O.C., Ahwa, V.P., and Naik, M.S. 1971. Soil fertilizer levels and protein quality of wheat grains. Australian Journal of Agricultural Research. v. 22, No. (2), pp 195-200.
- Albanese, A.A. 1967. Newer Methods of Nutritional Biochemistry, Volume III, pp 130.
- Alyamamah Magazine. 1982. N.691, pp 18-22. Riyad, Saudi Arabia.
- American Association of Cereal Chemists. 1976. Approved Methods of the AACC.
- Association of Official Analytical Chemists. 1979. Method of Analysis. Washington, D.C.
- Awadalla, M.Z. and Slump, P. 1974. Native Egyptian Millet as supplement of wheat flour in bread. Nutritional Study, Nutrition Reports International, v. 9, No. 1, pp 59-68.
- Brenna, S.L., Stenvert, N.L. and Moss, H.T. 1979. Milling quality studies recovery of protein and B Group vitamins in milling some Australian wheats. Food Technology in Australia. Vol. 23, pp 400-401.
- Clausi, A.S. 1971. Cereal grains and dietary protein sources for developing highly acceptable high protein food. Food Technology, v. 25, pp 821-825.
- Davis, K.R., Cain, R.F., Peters, L.J., Letournea, D. and McGeinnis, J. 1981. Evaluation of the nutrient composition of wheat. II. Cereal Chemistry. v. 58, No. 2, pp 116-120.
- El-Ghamry, M.T. and Stare, F.J. 1975. Determination of effectiveness of amino acid fortification of Tunisian wheat flour. Abstracts.
- FAO/WHO. Protein requirements, Rome. FAO Nutrition Meeting Report Series. No. 37. 1965.
- Haber, T., Seyam, A.A. and Banasik, O.J. 1976. Rheological properties, amino acid composition and bread quality of hard red winter wheat, rye and triticale. Bakers Digest. v. 50 (3) pp 24-27.

Hamad, A.M. and Fields, M.L. 1979. Nutritional and sensory evaluation of bread and corn chips made from fermented wheat and corn meals. *Fd. Sci. Technol.*, pp 17-18.

Holland, R..B and Ritchie, W.S. 1941. Trace metals and total nutrient in human and cattle food. *Mass. Agric. Exp. Stn. Bull.* 379.

Hussein, L., Abbussy, M., Arafa, A. and Marcos, S.R. 1979. Evaluation of the protein quality of wheat grains and sight-related products by the close response bioassay. *Zeitschrift fuer Ernaehrung Swiss Enschafft*, v. 18, pp 275-285.

Keagy, P.M., Borenstein, B., Ranum, P., Connor, M.A., Lorenz, K., Hobbs, W.E., Hill, G., Bachman, A.L., Boyd, W.A., and Kulp, K. 1980. Natural levels of nutrients in commercially milled wheat flours. II. Vitamin Analysis. *Cereal Chemistry*. v. 57, pp 59-65.

Knight, E.M. and Okoro, C. 1980. The effect of toasting on the amino acid composition and utilization of protein from unsupplemented and soybean supplemented white bread. *Federation Proceedings*. v. 39 (3-II), pp 1115.

Koivistoinen, P., Nissiven, H, Varo, P. and Ahlstrom, A. 1974. Mineral element composition of cereal flour and flakes. *Acta Agriculturae Scandinavica*. No. 24, pp 323-326.

Kulp, K., Ranum, P.M., Williams, P.C. and Yamazaki, W.T. 1980. Natural levels of nutrients in commercially milled wheat flours. I. Description of samples and proximate analysis. *Cereal Chem.* v. S7(1), pp 54-58.

Lorenz, K., Loewe, R., Dwea and Wolf, W. 1980. Natural levels in commercially milled wheat flour. III. Minerals Analysis. *Cereal Chemistry*, v. 57, pp 65-69.

Lorenz, K. and Loewe, R. 1977. Mineral composition of U.S. and Canadian wheat and wheat blends. *J. Agric. Food Chem.* v. 25 No. 4, pp 806-809.

Marston, R. and Friend, B. 1976. Nutritional Review. *National Food Situation*, v. 158, pp 25.

Miladi, S., Hegsted, D.M., Saunders, R.M. and Koehler, G.O. 1972. The relative nutritive value, amino acid content and digestibility of the proteins of wheat mill fraction. *Cereal Chemistry*. v. 49, pp 119-127.

- Miller, E.L. 1967. Determination of the tryptophan content of feeding stuffs with particular reference to cereal. *J. Sci. Fd. Agric.* v. 18, pp 381-386.
- Mitva, G.N. and Das, N.B. 1971. Protein quality of high yielding varieties of rice. *J. Agr. Food Chem.* v. 19, pp 927-929.
- Mitchell, H.H. and Block, R.J. 1946. Some relationship between the amino acid contents of proteins and their nutritive values for the rat. *J. Biol. Chem.* v. 163, pp 549-620.
- Mahoney, A.W., Lopez, J.G. and Hendricks, B.G. 1975. An evaluation of the protein quality of quinoa. *J. of Agr. and Food Chem.* v. 23(2), pp 190-193.
- Nelson, P.N. and McDonald, C.E. 1977. Properties of wheat flour protein in flour from selected mill streams. *Cereal Chemistry.* v. 54, pp 1182-1191.
- Orth, R.A., Oliver, J.R. and Rayner, C.J. 1976. Composition and nutritional value of protein of wheat flour streams. *Food Technology in Australia.* v. 28, pp 210-214.
- Pomeranz, Y., Dikeman, E., and Lai, F.S. 1982. Minerals and protein content in hard red winter wheat. *Cereal Chem.* v. 5a(2), pp 139-142.
- Ranum, F.F., Barrett, R.J., Loewe and Kulp, K. 1980. Nutrient levels in internationally milled wheat flour. *Cereal Chemistry,* v. S7, pp 361-366.
- Sikka, K.C., Johari, R.P., Duggal, S.K., Ahuja, V.P. and Austin, A. 1975. Comparative nutritive value and amino acid content of different extraction of wheat. *Journal of Agricultural and Food Chemistry.* v. 23, pp 24-26.
- Simmonds, H. 1962. Variations in the amino acid composition of Australian wheat and flour. *Cereal Chem.* v. 39, pp 445.
- Spier, J.R. and Chambers, D.C. 1949. Chemical determination of tryptophan in protein analytical chemistry. *21(10):* pp 1249-1266.

Tabekhia, M.M. and Mohammed, M.S. 1971. Effect of processing and cooking operation on thiamine, riboflavin, and nicotinic acid content of some Egyptian national food, wheat flour, bread and rice. Alexandria Journal of Agricultural Research. v. 19, pp 279-284.

U.S. Department of Agriculture Survey cited in Pomeranz, Y. Wheat Chemistry and Technology. American Association of Cereal Chemists. St. Paul. 1971. p 727.

Waines, J.G., Labanauskas, C.K., Handy, M.F., Gill, B.S., and Lehman, W.F. 1978. Protein and amino acid profiles of normal and yellow-berry bread wheat. Crops Science. v. 18(4), pp 5900-5920.