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EFFECT OF PARBOILING ON THE VITAMIN CONTENT AND STORAGE QUALITY OF WHEAT

by

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EFFECT OF PARBOILING ON WHEAT

Tannous

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ABSTRACT

"Burghul", or parboiled wheat, is one of the most important cereal products in the Middle East. It is prepared by boiling wheat in water until the grains can be easily crushed with the fingers. After drying the parboiled wheat, it is ground and the bran is removed.

Previous studies on rice have shown that a redistribution of the water-soluble nutrients, especially the B vitamins, occurs upon parboiling. However, very little research has been carried out to study the effect of parboiling on the B vitamins in wheat.

In this study, samples from a soft wheat variety, Florence Aurore, and a hard variety, Senator Capelli were parboiled in water boiling at atmospheric pressure or under 15 psi pressure, for the conventional parboiling time, i.e. when grains are easily crushed by fingers, or half that time. The effect of these various parboiling treatments on the thiamine, riboflavin and niacin contents as well as the storage quality of the two wheat varieties was studied over a three-month storage period. Thiamine was determined by the thiochrome method, riboflavin was determined fluorometrically and niacin was assayed microbiologically. The peroxidase activity was taken as an index of the storage quality because of the heat stability of peroxidase.

The parboiling process was found to have direct destructive effect on thiamin. However, the niacin content of the parboiled samples was increased due to a redistribution of the vitamin, from the outer layers of the grain to the inner layers. Riboflavin, being evenly distributed within the grain, was not affected by parboiling.

The soft wheat variety, Florence Aurore, was found to retain less of its thiamine, riboflavin and niacin than the hard variety, Senator Capelli. This may be due to the ease of heat penetration through soft wheat.

While some thiamine in the parboiled samples was destroyed during the three-month storage period, little change was noted in the riboflavin and niacin levels.

All parboiling treatments were found to be sufficient to inactivate peroxidase and thus presumably all native enzymes in wheat.

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INTRODUCTION

Cereal products constitute a large part of the human diet in the Middle East (1). Of these, one of the most important is parboiled wheat or "Burghul". A similar product known in Turkey is called "Bulgur" and sometimes referred to as "Burgul" (25).

Although "Burghul" is a very common food in the area and enters in the preparation of many dishes, little research has been conducted to study the nature of this product.

The present work is an attempt to evaluate the parboiling process with regard to the nutritive value of wheat.

REVIEW OF LITERATURE

I. The Parboiling of Wheat

Parboiled wheat or "Burghul" is prepared generally by the following method (9) (27):

Wheat is separated from the chaff and washed in cold water. Then it is placed in an uncovered round-bottom copper kettle with sufficient amount of water. The wheat is heated in boiling water, with occasional stirring, until the grains can be easily crushed between the fingers. During parboiling, most of the water is either evaporated or absorbed into the wheat.

The grains are removed with a sieve-like ladle and spread in layers to dry in the sun. The wheat is spread on jute bags, straw mats, or on cement ground and turned once or twice a day for 2 to 3 days until dry. At this stage the wheat has a yellow-brown color, and may be packed and stored in jute bags for several years.

Before grinding, the parboiled wheat is moistened with a sprinkle of water. In Turkey (24), it is beaten and fanned to separate the hulls. The grinding is done in a stone mill, which can be adjusted to give different sizes.

The origin of the parboiling process and the reasons for its development are not clear. However, it has been observed that crushed parboiled wheat when soaked or cooked in water will remain in separate grains, while unboiled crushed wheat will lump when soaked in water. This is important in the preparation of certain dishes from "Burghul".

From the nutritional and biochemical points of view there may be several advantages to the parboiling process. As with rice, parboiling may bring about redistribution of vitamins within the grain and improvement

of the nutritive value of the product (14). Furthermore, it is known that parboiling causes denaturation of proteins and so inactivates the enzymes. In this respect, the process probably serves as a means of preserving wheat.

II. Effect of Parboiling on Certain Nutrients in Wheat

The principal changes taking place in the processing of cereal products are losses in vitamin content, decrease in nutritive value of the proteins, and beneficial effect on calcium absorption caused by the destruction of phytic acid (11). Of these changes, the loss of vitamins, particularly thiamine, riboflavin and niacin, is of interest in this study. It was shown by Maynard (18) that whole wheat is one of the best sources of these vitamins.

Hegsted et al. (11) found that the vitamin content of wheat may vary considerably depending on variety, climate, composition of soil, harvesting and handling procedures. It was also noticed that the levels of thiamine, riboflavin, and niacin were directly related to the protein level of wheat.

Calhoun et al. (6) showed that thiamine is largely concentrated in the scutellum, while niacin is concentrated in the outer layers of the wheat grain. Riboflavin seems to be higher in the embryo and the aleurone layer than in the other fractions of the grain (15).

The effect of parboiling has been well studied with rice. Hinton (14) found that parboiling results in a higher content of the B vitamins in milled rice. This was explained as being due to a redistribution of the vitamins within the grain, so that the endosperm is considerably enriched, as shown in Table 1.

Table 1. The Effect of Parboiling on the Distribution of Thiamine between the Germ and the Endosperm of the Rice Grain.

Treatment of wheat	Germ (Scutellum and embryo)	Endosperm
	(mcg thiamine per gm)	
Untreated	44.0	0.44
Parboiled	9.5	5.2
Parboiled	8.7	4.6

Data from: Hinton, J.J.C. Parboiling Treatment of Rice. Nature, 162, 913 (1948).

Hinton observed that the redistribution of thiamine depends mainly on the water condensing on the surface of the grain and penetrating into the geletinizing endosperm. The extent of redistribution of thiamine did not change considerably when steaming was replaced with hot water at 75°C. This suggests that parboiling temperature alone has no effect on the thiamine redistribution.

Sakurai (22) found that when brown rice was soaked in water at 37°C for 5 hours or at 25° for 19 hours, 50% of the thiamine of the bran and the embryo was transferred into the endosperm, and about 10% was lost into the soaking water. However, the loss could be decreased by soaking the rice at higher temperature for less time and by using a smaller volume of soaking water. It was also found that the amount of thiamine transferred into the endosperm was greater when boiling in 2% aqueous sodium chloride solution than in tap water. This transfer was thought to be due to diffusion during soaking accompanied by absorption into the starch during heating, i.e. formation of α-starch as examined by Kihara's diastase method (16) was found to be in the decreasing order in boiled, parboiled, and uncooked rice, respectively. Similarly,

Swaminathan (28) showed that parboiling ensures greater protection for thiamine in rice by insulating it, by virtue of the starch effect. As Nicholls (21) explains this effect, gelatinization of the starchy endosperm beneath the germ during parboiling acts as a cementing layer so that the germ, which is high in thiamine, is not easily knocked out during milling.

Shammas and Adolph (27) carried out a comprehensive study on the effect of parboiling on wheat constituents. Wheat was assayed for the different constituents, then a portion of the wheat was parboiled and assayed for the same constituents. The results are shown in Table 2.

Table 2. The Chemical Composition of Wheat and its Parboiled Product.

Constituents	Wheat	Parboiled wheat
Moisture %	9.4	10.3
Protein (% on dry basis)	13.5	13.0
Fat (% on dry basis)	2.5	2.5
Ash (% on dry basis)	1.7	2.0
Carbohydrates - by difference (% on dry basis)	82.1	82.3
Thiamine (mg/100 gm dry matter)	0.55	0.34
Riboflavin (mg/100 gm dry matter)	0.12	0.03
Niacin (mg/100 gm dry matter)	4.75	5.34

Data calculated from: Shammas, E. and Adolph, W.H. The Nutritive Value of Parboiled Wheat Used in the Near East. J. Am. Dietet. Assoc., 30, 982 (1954).

It is clear from Table 2 that thiamine and, to a greater extent, riboflavin have decreased considerably during the parboiling process

while niacin increased slightly. The authors have related the great loss in riboflavin to the exposure to sunlight during drying. However, the slight increase in niacin may be due to the redistribution of this vitamin from the outer layers of the grain into the inner layers, thus avoiding loss in the separation of the bran.

Saracoglu (24) (25) investigated the thiamine and riboflavin contents of Turkish wheat and its parboiled product, "Bulgur", from various regions. It was found that thiamine decreased, on the average, from 3.9 mcg per gm of wheat to 2.8 mcg per gm of the parboiled product, with a loss of about 27%. The parboiled wheat was found to contain about 73% less riboflavin than the untreated grains. This was explained to be due to boiling in water, and separating the hulls and the fine particles, which were found to be relatively high in riboflavin.

III. Effect of Parboiling on Storage Quality of Wheat.

The changes taking place in wheat during storage have been divided by Anderson and Alcock (2) into those occurring in carbohydrates, proteins, fats, minerals and vitamins. These changes are catalyzed by enzymes usually found in wheat. Since the parboiling of wheat is expected to inactivate the native enzymes, it may be considered as a means of preservation. The enzyme activity of wheat and its parboiled product may then be considered as an index of deterioration.

Kent-Jones and Amos (15) studied enzymes that are generally found in wheat and classified them into: 1. diastatic enzymes, that breakdown starch into sugars, 2. proteolytic enzymes, that breakdown proteins into peptones, peptides and amino acids, 3. lipases, that hydrolyse fat into free fatty acids and glycerol, and 4. peroxidases

that catalyze the breakdown of peroxides. Of all these enzymes, the peroxidases are considered the most heat-stable. This makes the assay of peroxidase activity a suitable test for the efficiency of the parboiling process in wheat. Heiss (12) has used the peroxidase activity test to evaluate the efficiency of the steaming of oats.

STATEMENT OF PROBLEM AND PLAN OF INVESTIGATION

This investigation is a study of the effect of the parboiling process on the retention of thiamine, riboflavin and niacin in two varieties of wheat, one soft and the other hard and on the storage quality of the parboiled products.

The two varieties of wheat used are: I Florence Aurore, and II Senator Capelli, the former being a soft variety while the latter is a hard wheat.

Samples from each variety received various parboiling treatments, as being: 1 - Boiled in water at atmospheric pressure; 2 - Boiled in steam under a pressure of 15 psi, corresponding to a temperature of 120°C; or 3 - Not-boiled, to act as a control. The time of the parboiling process was either: (a) for the normal time; as practiced commercially and until the grains were easily crushed with the fingers; or (b) for half-conventional time, i.e. half the time that is considered normal.

In this study, the prepared samples were stored at room temperature for 3 months. Every month, a portion of each treatment was assayed for thiamine, riboflavin and niacin. The peroxidase activity was also to be tested as an index of the shelf-life during storage.

The plan of investigation is briefly summarized in Table 3.

Table 3. The Summarized Plan of Investigation.

Code No. of sample	Variety of wheat	Weight of sample (gm)	Parboiling Temperature (°C)	Parboiling Time (Minutes)
I-3-0	Florence Aurore	800	-	0
I-1-b	Florence Aurore	800	100	30
I-1-a	Florence Aurore	800	100	60
I-2-b	Florence Aurore	800	120	5
I-2-a	Florence Aurore	800	120	10
II-3-0	Senator Capelli	800	-	0
II-1-b	Senator Capelli	800	100	30
II-1-a	Senator Capelli	800	100	60
II-2-b	Senator Capelli	800	120	5
II-2-a	Senator Capelli	800	120	10

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EXPERIMENTAL

I. Materials and Methods

Preparation and Storage of Samples:

The two varieties of wheat used in this study, i.e. Florence Aurore and Senator Capelli, were obtained from the American University Farm in the Bekaa Plain.

Five samples, each of which weighed 800 gm, were prepared from each variety. Each sample was exposed to the proper heat treatment as designated in Table 3. For the samples boiled in water at atmospheric pressure, water was added in such an amount that all of it was absorbed by the time boiling was checked. In this case, a sample of 800 gm of Florence Aurore required 2200 ml of water for conventional time boiling and 1000 ml for half-conventional treatment while a similar sample of Senator Capelli absorbed 1500 ml of water in normal parboiling and 900 ml in half-conventional treatment. This eliminated the leaching of the water soluble vitamins; thiamine, riboflavin and niacin.

The boiled samples were spread on trays and placed in a forced-draft dehydrator to dry.

The dried samples were sprayed with a little water then they were ground in a Wiley mill and left on trays overnight to dry at room temperature.

The ground samples were seived in a forced-draft. The bran, being lighter in weight than the rest of the grain, was separated in a draft of air and was discarded.

The samples were kept in tightly closed glass jars and stored at room temperature for 1, 2 or 3 months.

Assay Methods

1. Moisture Determination:

Samples of about 3 gm, crushed to 40-mesh, were accurately weighed in moisture pans that had been desiccated overnight. They were placed at a temperature of 100°-105°C for 5 to 6 hours. Samples were then cooled in a desiccator and weighed. They were further heated at 100°-105°C for 1 or 2 hours then weighed again. This was repeated until two successive weighings were the same.

The moisture content of the samples was calculated on percentage basis.

2. Thiamine Assay:

Thiamine was determined by oxidizing it quantitatively to thiochrome which fluoresces in ultraviolet light. The fluorescence was considered proportional to the amount of thiochrome and hence to the thiamine originally present in the sample (18).

A 40-mesh sample of about 5 gm was accurately weighed into a 100-ml volumetric flask. The sample was then extracted with 75 ml of 0.1 N HCl for 30 minutes in a boiling water bath with occasional stirring.

The extract was cooled to lower than 50°C and 5 ml of freshly prepared Taka-diastase suspension[1] were added to digest the starch and release free thiamine from its phosphate ester (5). The mixture was then incubated at 37°C overnight.

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1. This is prepared by suspending 6 gm of Taka-diastase in 2.5 M sodium acetate solution and diluting to 100 ml.

The extract was allowed to cool to room temperature and was diluted with water to 100 ml. These were mixed thoroughly and filtered, discarding the first few millileters of the filtrate.

An adsorption tube fitted with small plug of glass wool was filled with water and about 5 gm of activated Decalso[2] were allowed to fall into the tube by gravity.

Water was drained from the adsorption tube and 25 ml of the prepared extract were pipetted into the reservoir. The Decalso was washed with three successive portions, about 10 ml each, of hot water, discarding the filtrate and the washings.

After washing,two 10-ml portions of acid potassium chloride solution[3] were placed in the reservoir and the eluate was collected in a 25-ml volumetric flask. The contents were then diluted to the mark with acid potassium chloride solution. A 25-ml aliquot of thiamine standard solution[4] was also purified in a similar manner.

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2. Decalso is activated in a Buchner funnel by adding 250 ml of hot 3% acetic acid to 100 gm of Decalso and keeping it in contact for 15 minutes. Then after draining the solution, the washing is repeated with 250 ml of hot 3% acetic acid, 250 ml of hot 25% KCl, 250 ml of hot 3% acetic acid, and finally with 600 ml of hot water until the final wash is chloride-free. The activated Decalso is dried at below 100°C and stored in a stoppered bottle.

3. This is prepared by diluting 8.5 ml of conc. HCl to one liter with 25% KCl.

4. This is prepared by transferring 2 ml of a stock thiamine solution to a flask containing 750 ml of 0.1 N H_2SO_4 and 50 ml of sodium acetate solution and adjusting the volume to one liter with water. The stock thiamine solution is prepared by dissolving 100 mg of desiccated dry thiamine chloride in 25% ethanol and diluting to one liter with the same solvent.

Two 5-ml aliquots of the acid potassium chloride eluate of each of the sample and the standard were pipetted into two test tubes. To one test tube, 3 ml of alkaline ferricyanide solution[5] were added and mixed gently, and to the other tube 3 ml of 15% sodium hydroxide solution were added. Immediately, 20 ml of isobutyl alcohol were added into each of the two tubes. The contents were shaken vigorously for 90 seconds.

The test tubes were allowed to stand until the two phases separated and the lower aqueous layer was siphoned out. About three grams of anhydrous sodium sulfate were then added to the remaining isobutyl alcohol layer. The extracts were shaken for 30 seconds, then refrigerated for few minutes.

About fifteen milliliters of the clear, colorless isobutyl alcohol solution were decanted into separate matched cuvets. The fluorescence was determined, in terms of galvanometric deflections, with "Lumetron" photoelectric fluorescence meter[6] using quinine sulfate solution[7] as standard.

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5. This is prepared by diluting 3 ml of 1% potassium ferricyanide to 100 ml with cool 15% NaOH solution.

6. Manufacture by PHOTOVOLT Corporation, 95 Madison Avenue, New York, N.Y., U.S.A.

7. The solution is prepared by diluting 3 ml of stock quinine sulfate to one liter with 0.1 N sulfuric acid; the stock quinine sulfate being prepared by dissolving 100 mg of quinine sulfate and diluting to one liter with 0.1 N sulfuric acid.

The thiamine content of the sample was calculated, in mcg per gm dry matter, as:

$$\frac{U - UB}{S - SB} \times \frac{1}{5} \times \frac{25}{V} \times \frac{100}{\text{wt. dry matter in sample}}$$

where U = deflection of unknown

UB = deflection of unknown blank

S = deflection of standard

SB = deflection of standard blank

V = volume of solution used for the adsorption on Decalso.

The factor $\frac{1}{5}$ converts the reading to mcg per ml instead of mcg per 5 ml aliquot.

3. Riboflavin Assay:

The fluorescence method used for determining riboflavin (18) is based on the difference in fluorescence before and after the chemical reduction of riboflavin.

A sample of about 3 gm, that had been crushed to 40-mesh, was weighed accurately into a 125-ml Erlenmeyer flask. After adding 50 ml of 0.1 N HCl, the mixture was autoclaved at a pressure of 15 psi for 30 minutes, then cooled.

The pH value was adjusted to 6.0 with 1 N sodium hydroxide, swirling the sample constantly since riboflavin is unstable in alkaline solution. The pH was then brought to 4.5 with 1 N HCl. The adjusting of pH between 4.5 and 6.0 is necessary to precipitate any interfering impurities, especially proteins. The solution was then transferred to a 100-ml volumetric flask and diluted to the mark with water.

The extract was filtered and 1 N HCl was added dropwise to a 50-ml aliquot of the filtrate until no more precipitate formed. This was followed by adding an approximately equal number of drops of 1 N HaOH with constant shaking. The mixture was then diluted to 100 ml with water and filtered again, if necessary.

Each of two 10-ml aliquots of the extract was mixed with 1 ml of water in a test tube. This was repeated in two other test tubes, only mixing the 10-ml aliquot of the extract with 1 ml of riboflavin standard solution[8]. To each of the four test tubes, 1 ml of glacial acetic acid was added.

The riboflavin in the extract was oxidized by adding 0.5 ml of 3% potassium permenganate to each test tube and mixing well. The tubes were then allowed to stand for exactly 2 minutes when 0.25 ml of 3% H_2O_2 was added and mixed thoroughly. The color of the solution disappeared within 10 seconds.

Using a "Lumetron" photoelectric fluorescence meter with sodium fluorescein solution[9] as a standard, the fluorescence of the extracts containing added water was measured (Reading "A"). Then approximately 20 mg of sodium hydrosulfite ($Na_2S_2O_4$) were added to the cuvets to

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8. This is prepared immediately before use by diluting 1 ml of a stock riboflavin solution with water to 50 ml. The stock riboflavin solution is prepared by transferring 50 mg of desiccated riboflavin to a 2-liter flask, adding 1500 ml water and 2.4 ml glacial acetic acid warming the solution, then making volume to 1 liter with water.

9. This is prepared by diluting 1 ml of a stock sodium fluorescein solution to 1 liter with water. The stock solution is prepared by dissolving 50 mg of sodium fluorescein in one liter of water.

destroy the riboflavin fluorescence, measuring the fluorescence within 10 seconds (Reading "C"). Finally the fluorescence of the extracts containing added riboflavin was measured (Reading "B").

The riboflavin content of each sample was calculated from the following formula:

$$\frac{A - C}{B - A} \times \frac{\text{riboflavin increment}}{\text{10-ml aliquot}} \times \text{dilution factor} \times \frac{1}{\text{dry weight of sample}}$$

= mcg riboflavin per gm dry matter.

4. Niacin Assay:

Niacin was determined by a microbiological technique (18), where a niacin-requiring microorganism is grown on a niacin-free medium, supplemented with various dilutions of standard and unknown solutions. The growth responses are then measured and compared quantitatively.

The material to be assayed was ground in a micro-mill to pass through a 40-mesh screen. A sample of about 2.5 gm was weighed accurately and mixed thoroughly with 100 ml of 1 N H_2SO_4 in a 250-ml Erlenmeyer flask. The mixture was autoclaved at 15 psi for 30 minutes. The extract was adjusted to pH 6.8 using 1 N NaOH, and was diluted with water to make one liter. The solution was then filtered through Whatman No. 40 filter paper.

To duplicate tubes, 0.5-, 1.0-, 2.0-, and 3.0- ml aliquots of the filtrate were added. Sufficient water was then added to bring the volume in each tube to 5.0 ml. The basal medium[10] was added at the rate of 5 ml per tube.

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10. Bacto-Niacin Assay Medium, manufactured by DIFCO Laboratories, Detroit, Michigan, U.S.A. was used.

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To duplicate tubes, 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 4.0 ml of the niacin standard solution[11] were added. Sufficient water was then added to bring the volume in each tube to 5.0-ml. To each of these tubes, 5.0 ml of the basal medium were added.

The contents of each tube were mixed thoroughly and the tubes were covered with caps, then autoclaved at 15 psi for 15 minutes. The tubes were then cooled to room temperature.

A stock culture of <u>Lactobacillus arabinosus</u>, ATCC 8014[12], was obtained by making two stab transfers every two weeks into stock agar medium[13], incubating at 37°C for 16-24 hours then storing in a refrigerator under aseptic conditions.

On the day before use, cells from the stock culture were transferred to a sterile tube of inoculum culture medium[14] and incubated at 37°C for

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11. This is prepared on the day it is used by diluting 1 ml of a standard niacin stock solution to one liter with water. The stock solution is prepared by dissolving 50 mg of desiccated anhydrous crystalline niacin in 500 ml of 50% ethyl alcohol.

12. Obtained from the American Type Culture Collection 2029 M Street, N.W., Washington 6, D.C., U.S.A.

13. This is prepared by dissolving 5 gm peptone, 1 gm yeast extract, 10 gm anhydrous glucose, 10 gm anhydrous sodium acetate, 5 ml salt solution A (25 gm of K_2HPO_4 in 500 ml water), 5 ml salt solution B (10 gm $MgSO_4 . 7H_2O$, 0.5 gm NaCl, 0.5 gm $FeSO_4 . 7H_2O$, 0.5 gm $MnSO_4 . 4H_2O$ in 500 ml water then adding 5 drops of conc. HCl in 200 ml water). The pH is adjusted to 6.8 with 1 N NaOH and then dilute to 500 ml, 7.5 gm of agar are added and boiled. While hot, 10-ml aliquots are put in test tubes, plugged, and autoclaved at 15 psi for 15 minutes.

14. This is prepared in the same manner as the stock agar medium (footnote 13) but without the addition of agar to the nutrient solution.

16-24 hours. The tube was centrifuged, with the cap secured with an adhesive band. The supernatent liquid was decanted and the cells were resuspended aseptically in 20 ml of sterile isotonic salt solution (0.9% sodium chloride). A sterile syringe with a 20 gauge needle was filled with the cell suspension and used at once for inoculation of assay tubes. Each tube was inoculated aseptically with one drop of inoculum from the syringe and inocubated at 37°C for approximately 72 hours.

To each tube, 2 or 3 drops of 0.1% bromothymol blue were added, and the contents were titrated with standard 0.1 N NaOH to a green color end point.

A standard curve for the assay was drawn by plotting the volume of 0.1 N NaOH used in titrating each of the standard tubes against the niacin concentration in each tube.

The niacin content of the tubes in the unknown series was determined by interpolation of the titre values on the standard curve. Any values showing more than 0.4 or less than 0.05 mg of niacin per tube were discarded. The niacin content of each milliliter of test solution was calculated for each of the duplicate sets of tubes.

The niacin content of the test material was calculated from the average values for 1 ml of test solution, obtained from not less than three sets of these tubes which did not vary by more than 10% from the average, using the following formula:

$$\text{mcg niacin per gm dry matter} = \frac{\text{average mcg per ml} \times \text{volume of sample extract}}{\text{dry matter in sample}}$$

5. Peroxidase Activity Test:

The peroxidase activity test is based on the fact that peroxidase catalyzes the conversion of hydrogen peroxide into water and oxygen (19).

A sample of about 2 gm was soaked in water for 24 hours then spread over a clean towel to dry. The dried sample was ground in a micro-mill to pass through a 40-mesh screen and a 250 mg portion was suspended in 10 ml water.

To the suspension, 10 drops of 2% gum guaiac in alcohol were added immediately followed by 10 drops of 3% hydrogen peroxide solution. The time required to produce a blue color was measured and compared with a standard (10).

II. Results

Data obtained in the course of this investigation have been reduced to tabular form and are presented in Tables 4-8, inclusive.

Table 4. Moisture Content of Wheat and its Parboiled Products During Three-month Storage.

Wheat Variety and Treatment	Moisture Content (%)			
	Freshly Prepared	Stored one month	Stored two months	Stored three months
Florence Aurore				
Unboiled	12.1	12.5	12.4	14.3
Boiled, half-conventional time, at atmospheric pressure	11.4	10.8	11.6	11.2
Boiled, conventional time, at atmospheric pressure	11.7	11.9	11.7	12.5
Boiled, half-conventional time, at 15 psi pressure	11.6	10.3	11.8	10.3
Boiled, conventional time, at 15 psi pressure	12.2	11.7	12.1	14.2
Senator Capelli				
Unboiled	11.9	11.8	12.2	12.9
Boiled, half-conventional time, at atmospheric pressure	11.9	9.9	11.6	10.6
Boiled, conventional time, at atmospheric pressure	11.8	11.4	12.0	12.3
Boiled, half-conventional time, at 15 psi pressure	10.4	10.3	10.6	10.9
Boiled, conventional time, at 15 psi pressure	10.9	10.8	11.0	11.4

Table 5. Thiamine Content of Wheat and its Parboiled Products During Three-month Storage.

Wheat Variety and Treatment	Thiamine Content (mcg per gm dry matter)			
	Freshly prepared	Stored one month	Stored Two months	Stored Three months
<u>Florence Aurore</u>				
Unboiled	4.8	4.4	4.6	4.6
Boiled, half-conventional time, at atmospheric pressure	3.8	3.3	3.6	3.7
Boiled, conventional time, at atmospheric pressure	2.9	2.9	2.5	2.6
Boiled, half-conventional time, at 15 psi pressure	3.7	3.1	3.5	2.8
Boiled, conventional time, at 15 psi pressure	3.2	2.9	2.2	2.3
<u>Senator Capelli</u>				
Unboiled	4.6	4.6	4.8	4.7
Boiled, half-conventional time, at atmospheric pressure	3.9	4.0	4.0	3.9
Boiled, conventional time, at atmospheric pressure	3.6	3.9	5.2	3.5
Boiled, half-conventional time, at 15 psi pressure	4.0	4.3	3.7	3.6
Boiled, conventional time, at 15 psi pressure	3.7	3.8	3.6	3.1

Table 6. Riboflavin Content of Wheat and its Parboiled Products During Three-month Storage.

Wheat Variety and Treatment	Riboflavin Content (mcg per gm dry matter)			
	Freshly prepared	Stored one month	Stored two months	Stored three months
Florence Aurore				
Unboiled	1.5	1.4	1.4	1.4
Boiled, half-conventional time, at atmospheric pressure	1.3	1.3	1.3	1.2
Boiled, conventional time, at atmospheric pressure	1.3	1.4	1.3	1.3
Boiled, half-conventional time, at 15 psi pressure	1.3	1.3	1.3	1.3
Boiled, conventional time, at 15 psi pressure	1.4	1.4	1.4	1.3
Senator Capelli				
Unboiled	1.3	1.3	1.3	1.3
Boiled, half-conventional time, at atmospheric pressure	1.2	1.2	1.2	1.2
Boiled, conventional time, at atmospheric pressure	1.2	1.1	1.2	1.2
Boiled, half-conventional time, at psi pressure	1.3	1.2	1.3	1.2
Boiled, conventional time, at psi pressure	1.3	1.2	1.3	1.2

Table 7. Niacin Content of Wheat and its Parboiled Products During Three-month Storage.

Wheat Variety and Treatment	Niacin Content (mcg per gm dry matter)			
	Freshly prepared	Stored one month	Stored two months	Stored three months
Florence Aurore				
Unboiled	42	41	42	40
Boiled, half-conventional time, at atmospheric pressure	50	53	50	50
Boiled, conventional time, at atmospheric pressure	44	49	47	45
Boiled, half-conventional time, at 15 psi pressure	52	57	46	49
Boiled, conventional time, at 15 psi pressure	47	53	50	45
Senator Capelli				
Unboiled	40	52	40	41
Boiled, half-conventional time, at atmospheric pressure	50	58	49	46
Boiled, conventional time, at atmospheric pressure	47	57	50	48
Boiled, half-conventional time, at 15 psi pressure	51	59	50	50
Boiled, conventional time, at 15 psi pressure	48	58	47	48

Table 8. Peroxidase Activity in Wheat and its Parboiled Products During Three-month Storage.

Wheat Variety and Treatment	Peroxidase Activity Test.			
	Freshly prepared	Stored one month	Stored two months	Stored three months
Florence Aurore				
Unboiled	+	+	+	+
Boiled, half-conventional time, at atmospheric pressure	-	-	-	-
Boiled, conventional time, at atmospheric pressure	-	-	-	-
Boiled, half-conventional time, at 15 psi pressure	-	-	-	-
Boiled, conventional time, at 15 psi pressure	-	-	-	-
Senator Capelli				
Unboiled	+	+	+	+
Boiled, half-conventional time, at atmospheric pressure	-	-	-	-
Boiled, conventional time, at atmospheric pressure	-	-	-	-
Boiled, half-conventional time, at 15 psi pressure	-	-	-	-
Boiled, conventional time, at 15 psi pressure	-	-	-	-

DISCUSSION

All the laboratory-prepared parboiled samples, regardless of their heat treatment, appeared to be similar in color, texture, taste and odor to the commercially parboiled wheat.

Unlike the control, the parboiled grains were found to remain separate when soaked or cooked in water rather than clinging together. This characteristic may be due to the denaturation of wheat proteins and the gelatinization of starch brought about by the parboiling process.

The heat treatment seemed to have direct destructive effect on thiamine. While the samples that had been parboiled for the half-conventional time lost only 19% of their thiamine content, those parboiled for the full-conventional time lost about 31%. The temperature at which the wheat was parboiled seemed to have no significant effect on the thiamine content. This coincides with the findings of Hinton (14) in the parboiling of rice.

The data expressed in Table 5 show that while the wheat variety Florence Aurore lost about 42% of its thiamine content upon parboiling, the variety Senator Capelli lost only 21% of its thiamine. This indicates that parboiling brings about greater loss of thiamine in soft wheat than in hard wheat. It may be that heat penetrates more readily in the soft wheat grains than in the hard wheat.

The effect of parboiling on the riboflavin content of wheat did not seem to be as great as in the case of thiamine. The data in Table 6 show very little difference among the various parboiling treatments. However, it may be noted that the hard wheat variety retained slightly more of its riboflavin content than did the soft wheat variety.

This mild effect that parboiling seems to have on the riboflavin content of wheat may be due to the fact that riboflavin is more evenly distributed throughout the grain, thus allowing very slight redistribution and to the fact the parboiled samples were not exposed to direct sunlight in the course of their preparation. This would agree with Shammas and Adolph's interpretation (27) that the sundrying of parboiled wheat brings about a great loss in its riboflavin content.

The niacin content of each of the parboiled samples was higher than that of the control, as shown in Table 7. This is assumed to be due to the redistribution of the vitamin, from the outer layers of the grain to the inner layers, in the course of parboiling, thus avoiding loss in the separation of the bran.

The samples boiled for the half-conventional time to retain slightly more niacin than those receiving the full-conventional treatment. This may indicate that the half-conventional time was sufficient to carry out the redistribution of niacin and that excessive heating in the full-conventional treatment would bring about some destruction of the vitamin. The temperature of the parboiling process did not seem to cause any significant changes in the niacin content of the parboiled samples.

It may be noted, from the data reported in Table 7, that the soft wheat variety Florence Aurore retained slightly less niacin than did the hard wheat variety Senator Capelli. This may be due to greater heat penetration bringing about some destruction of the vitamin.

Upon storing the parboiled samples for three months, those boiled at 120°C seemed to lose more of their thiamine than those boiled at 100°C. However, the hard wheat variety Senator Capelli retained more of its thiamine

content than did the soft wheat variety. An explanation for these findings may lie in the changes occurring in other grain constituents, such as starch and proteins, brought about by the different parboiling treatments.

The riboflavin content of the parboiled samples did not change during the three-month storage period. This may be due to the storing of the samples away from direct sunlight.

It may be noted, from the data in Table 7, that the three-month storage period had little effect on the niacin content of the parboiled samples. This was expected, since niacin is considered to be a rather stable vitamin under the storage conditions provided in this study.

All the parboiling treatments tried in the course of this investigation have proved sufficient to inactivate the enzyme peroxidase and in turn all native enzymes in wheat. It is assumed that this would provide a product with longer shelf-life than the unboiled wheat.

SUMMARY

The effect of the parboiling process on the thiamine, riboflavin and niacin contents as well as the storage quality of two varieties of wheat, i.e. the soft variety Florence Aurore and the hard variety Senator Capelli, was studied.

While the parboiling process appeared to have direct destructive effect on thiamine, it brought about a redistribution of niacin, from the outer layers of the grain to the inner layers, thus increasing the niacin content in the parboiled samples over that in the unboiled wheat. Riboflavin, however, was not affected by parboiling since it is evenly distributed throughout the grain. However, the temperature of parboiling did not affect the thiamine, riboflavin or niacin contents of the wheat.

There was greater loss of these vitamins with the soft wheat variety Florence Aurore than with the hard wheat variety Senator Capelli. This may be due to great ease of heat penetration in the case of the soft wheat as compared to the hard wheat.

The three-month storage period brought about some loss in the thiamine content of the parboiled samples. However, very slight changes in the riboflavin or the niacin contents were observed on storage.

All the parboiled samples demonstrated good storage quality as indicated by enzyme inactivation.

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