Koerwer, J. F. (to Union Carbide Corp.) Canadian Patent 1 146 376, 1983.
Leonard, N. J.; Paukstelis, J. V. J. Org. Chem. 1963, 28, 3021.
Martin, D.; Graubaum, H. J. Prakt. Chem. 1979, 321(2), 315.
Payne, L. K., Jr. (Union Carbide Corp., South Charleston, WV), unpublished report, 1966.
Pellizzari, G.; Gaiter, A. Gazz. Chim. Ital. 1918, 48(II), 151.
Ward, C. E.; Berthold, R. V. (to Union Carbide Corp.) U.S. Patent 4 497 650, 1985.

Received for review January 21, 1986. Accepted June 24, 1986.

Effect of Processing on the Phytic Acid Content of Wheat Products

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The effect of processing on the phytic acid content of wheat and wheat products has been studied. Phytic acid is reduced significantly during the dough resting period at room temperature and on baking local leavened and unleavened flat breads. Addition of sodium bicarbonate for the preparation of Nan reduces the loss of phytic acid during the dough resting period. Roasting of wheat and preparation of Dalya (wheat porridge) result in reduction of phytic acid by 25 and 87.87%, respectively. Phytic acid is destroyed by 80.00–85.00% during the process of preparation of puri.

INTRODUCTION

Phytic acid is widely distributed in nature, and a large part of phosphorus in cereals and legumes is present in this form (Kent Jones and Amos, 1967). It is important for animal and human nutrition (Nelson, 1967; Taylor, 1965; McCance and Widdowson, 1942; Harrison and Mellanby; 1939, O'Dell and Sevage, 1960; Sharpe et al., 1950, Reinhold et al., 1973; Davies and Olpin, 1979; Oberleas, 1963), because of its ability to chelate several metals and thereby reduce their availability. Iron and zinc deficiencies occur in populations that subsist on unleavened whole-grain bread and rely on it as a primary source of these minerals. Deficiencies have been attributed to the presence of phytates (Reinhold et al., 1973; Oberleas, 1963; Reinhold, 1971; Haghshenass et al., 1972; Bruce and Callow, 1934). It causes rickets and bone deformation in young dogs (Harrison and Mellanby, 1939; Bruce and Callow, 1934).

Processing of cereals and legumes significantly reduces their phytic acid content. It has been reported that phytic acid conent is reduced during the process of baking leavened and unleavened Iranian flat breads (Ter-Sarkissian et al., 1974). According to Faridi et al. (1983), phytic acid of Iranian flat breads is reduced and the zinc availability is improved. It has been reported that phytic acid is reduced significantly during bread making (Pringle and Moran, 1942; Harland and Harland, 1980). No destruction of phytic acid takes place during the dough resting time and Chapati making process (Mehdi and Abrol, 1972). Cooking peas results in 13% phytate reduction (Beal and Mehta, 1985).

Wheat is the staple diet of Pakistan and is mainly consumed as leavened and unleavened flat breads, i.e. Chapati, Roti, and Nan. This paper deals with the effect of processing on the phytic acid content of wheat for the preparation of Pakistani leavened and unleavened flat breads and other wheat products.

EXPERIMENTAL SECTION

Materials and Methods. *Description of Pakistani Flat Breads. Chapati.* It is a round unleavened flat bread and is prepared from whole-wheat flour. The dough is covered with a moist muslin cloth and allowed to rest for 2 h at room temperature. The dough is then divided into small balls that are rolled into Chapati of desired diameter and thickness. The rolled dough is then baked on a hot plate until it attains light brown color on both sides.

Roti. Like Chapati it is also a round unleavened flat bread and is invariably prepared from whole-wheat flour. The whole-wheat flour dough after being kept for 2 h is divided into small balls that are then rolled as before for Chapati and stuck to the walls of previously heated dome-shaped earthen oven for baking. The baking time is 2–3 min. The heating material is wood, charcoal, or gas, and the temperature of the oven is about 550–600 °F.

Nan. It is a round leavened flat bread and is prepared from white flour known as Maida. The composition of Maida is included in Table I. The dough is made in the presence of salt and sodium bicarbonate (0.5%), covered with warm moist muslin cloth, and allowed to rest for about 2 h. The rest of the process is the same as for Roti.

Puri. The dough is made from white flour, i.e. Maida, in the presence of small quantities of salt and divided into small balls of about 40–50 g each. These are covered with a moist muslin cloth for about 1 h. Each ball is then rolled into thin circular shape. Puri of desired diameter is fried in hot edible oil to light brown or brown color. The frying time is about 15–30 s.

Roasted Wheat. The cleaned wheat is roasted in sand bath to light brown color until peculiar roasted wheat flavor is developed. Sand is then removed by sieving.

Dalya or Wheat Porridge. The roasted wheat is coarsely ground and fried in desired amount of edible fat for a short time. Water and sugar and/or salt are added and cooked into a porridge of desired thickness.

Whole-Wheat Flour (Chakki Ata). Wheat was purchased from the market, cleaned, and ground in a stone mill known as Chakki. In this type of mill the whole-wheat grain is ground to coarse flour that includes all parts of the whole seed.

Commercial wheat flour known as Ata is the coarse product obtained by roller milling cleaned and conditioned wheat and sieving it.

Maida is the fine product made by milling cleaned wheat and bolting the resulting wheat flour.

The composition of whole-wheat flour, commercial wheat flour, and Maida is given in Table I.

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0021-8561/86/1434-1010$01.50/0

Table I. Composition of Whole-Wheat Flour (Chakki Ata), Commercial Wheat Flour, and Maida

	composition, %					
sample descrp	moisture	protein	crude fat	ash	crude fiber	carbohydr
whole-wheat flour	10.84	10.50	2.10	2.10	1.30	74.46
commercial wheat flour	12.15	10.20	2.00	1.85	1.20	73.80
maida	13.96	9.15	0.50	0.66	0.45	75.73

Table II. Changes in Phytic Acid Content (% mfb)[a] during the Process of Preparing Local Flat Breads (Chapati, Roti, Nan) from Chakki Ata, Commercial Wheat Flour, and Maida

sample descrp	moisture, %	phytic acid, %	diff in phytic acid	% loss on bread making
whole-wheat flour (Chakki Ata)	10.84	1.20		
dough	56.84	0.86	0.34	28.33
Chapati	44.84	0.67	0.53	44.17
Roti	42.52	0.47	0.73	60.83
commercial wheat flour	12.15	1.22		
dough	53.35	0.89	0.33	27.05
Chapatt	43.68	0.68	0.54	44.26
Roti	42.35	0.52	0.70	57.38
Maida	13.96	0.26		
dough with 0.5% sodium bicarbonate	50.63	0.21	0.05	19.23
dough without sodium bicarbonate	50.60	0.18	0.08	30.77
Nan	43.00	0.04	0.22	84.62

[a] mfb = moisture-free basis.

Table III. Changes in Phytic Acid Content (% mfb)[a] of Wheat Grain during Preparation of Dalya (Wheat Porridge)

sample descrp	moisture, %	phytic acid, %	loss of phytic acid	% loss on making Dalya
wheat	10.6	1.32		
roasted wheat	9.6	0.99	0.33	25.00
Dalya	80.0	0.16	1.16	87.87

[a] mfb = moisture-free basis.

Table IV. Changes in Phytic Acid Content (% mfb)[a] of Maida during the Process of Puri Making

sample descrp	moisture, %	phytic acid, %	diff in phytic acid	% loss on Puri making
Maida	13.28	0.20		
dough	49.60	0.18	0.02	10.00
Puri (li brown)	31.70	0.04	0.16	80.00
Puri (brown)	31.00	0.03	0.17	85.00

[a] mfb = moisture-free basis.

Samples of Puri and dough and the Maida used for making the same puri and dough were obtained from a sweetshop where Puri is prepared and sold every morning as a breakfast food. Similarly samples of Nan and dough and the Maida used for the same dough and Nan were obtained from a Nan shop.

Phytate phosphorus was determined by the method of Wheeler and Ferrel (1971), which is briefly as follows. The samples of wheat and wheat products were extracted for 1 h with 3% trichloroacetic acid (TCA) with occasional swirling by hand. The suspension was centrifuged, and a definite volume of the supernatant was precipitated with a solution of ferric chloride (containing 2 mg of ferric iron/mL) in 3% TCA. The precipitate of ferric phytate was converted to ferric hydroxide with 1.5 N NaOH. The ferric hydroxide was dissolved in hot 3.2 N HNO_3 and the iron determined colorimetrically with 1.5 M KSCN. The absorbance of the solution was read immediately from a Hitachi spectrophotometer, Model No. 2205, at 480 nm against a reagent blank. The iron content was calculated from a previously prepared standard curve. The phytate phosphorous was calculated from iron determinations assuming a 4:6 iron to phosphorus molecular ratio. Phytic acid content was calculated on the assumption that it contains 28.20% phosphorus by weight, and phytic acid values as shown in Tables II–IV are based on single determinations.

DISCUSSION

Table II shows the changes in phytic acid content during the process of making Pakistani leavened and unleavened flat breads, i.e. Chapati, Roti, and Nan. Phytic acid is significantly reduced during dough keeping time (i.e., 2 h in this experiment for making Chapati, Roti, and Nan). This loss during dough keeping may be due to phytase activity naturally present in wheat flour. It has also been reported that reduction in phytic acid content during fermentation time is due to the action of phytase enzymes present in wheat and yeast (Pringle and Moran, 1933; Reinhold, 1975). Phytic acid is further reduced during baking Chapati, Roti, and Nan. The loss of phytic acid during baking Chapati and Roti from whole-wheat flour and commercial wheat flour is almost equal, and the average loss during baking Chapati and Roti is 44.21 and 59.10%, respectively. The loss of phytic acid during baking Nan is 84.62%. These results agree with the findings of Ter-Sarkissian et al. (1974) who have reported significant loss of phytic acid during the preparation of unleavened Iranian flat breads and are in contrast to the results reported by Mehdi and Abrol (1972). The later workers have reported that no phytic acid is destroyed during the dough resting and Chapati making process. The reduction in phytic acid content during dough resting time is less in the case of dough for Nan making, which may be due to the addition of sodium bicarbonate. In order to study the effect of sodium bicarbonate on the phytic acid conent during dough resting time for baking Nans, the dough was prepared with and without sodium bicarbonate. It is evident from Table II that loss of phytic acid is less in the presence of sodium bicarbonate. This confirms the results of Faridi et al. (1983) who have reported that addition of sodium bicarbonate in the Iranian flat bread formula lowers phytic acid hydrolysis during fermentation. The phytic acid content of Chakki Ata and commercial wheat flour is almost the same, which indicates that bran is not removed during the commercial milling process. Maida contains much less phytic acid than whole-wheat flour due to the removal of phytic acid rich parts of wheat kernel during milling wheat for the production of Maida.

Table III indicates that during roasting of wheat 25.00% phytic acid is reduced and during Dalya making the reduction is increased to 87.87%.

It is apparent from Table IV that in dough for Pur making the reduction in phytic acid content is 10.00%, which is much less than in dough for Nan making. This difference may be due to difference in dough resting time and enzymic activity. Frying the rolled dough (raw Puri) in edible oil to light brown color results into loss of up to 80.00% of phytic acid. Frying to brown color (well-done Puri), the loss of phytic acid is 85%, which shows that for preparing well-done Puri further loss of phytic acid is not significant.

ACKNOWLEDGMENT

We are thankful to Dr. M. K. Bhatty, Director, PCSIR Laboratories, Lahore, for giving permission to publish this paper. We are also grateful to Dr. Salah-ud-Din for his technical assistance. Muhammad Arshad is thanked for his cooperation and assistance.

Registry No. Phytic acid, 83-86-3.

LITERATURE CITED

Association of Official Agricultural Chemists *Official Methods of Analysis*, 10th ed.; Washington, DC, 1965.
Beal, L.; Mehta, T. O. *Food Sci.* **1985**, *50*, 96.
Bruce, H. H.; Callow, R. K. *Biochem. J.* **1934**, *28*, 517.
Davies, N. T.; Olpin, S. E. *Br. J. Nutr.* **1979**, *41*(3), 591.
Faridi, H. A.; Finney, P. L.; Rubenthaler, G. L. *J. Food Sci.* **1983a**, *48*(1), 107.
Faridi, H. A.; Finney, P. L.; Rubenthaler, G. L. *J. Food Sci.* **1983b**, *48*(6), 1654.
Haghshenass, M.; Mohloudji, M.; Reinhold, J. G.; Mohammadi, N. *Am. J. Clin. Nutr.* **1972**, *25*, 1143.
Harland, B. F.; Harland, J. *Cereal Chem.* **1980**, *57*(3), 226.
Harrison, D. C.; Mellanby, E. *Biochem. J.* **1939**, *33*, 1660.
Kent Jones, D. W.; Amos, A. O. *Modern Cereal Chemistry*, 5th ed.; The Northern Publishing Co: London, 1957; p 285.
McCance, R. A.; Widdowson, E. M. *J. Physiol.* **1942**, *101*, 44.
Mehdi, V.; Abrol, V. P. *Bull, Grain Technol.* **1972**, *10*(3), 187.
Nelson, T. S. *Poultry Sci.* **1967**, *41*, 862.
Oberleas, D. P. *Toxicants Occuring Naturally in Foods*; Strons, F. M., Ed.; National Academy of Science; Washington, Dc, 1973; 3636.
O'Dell B. L.; Sevage, J. E. *Proc. Soc. Exp. Biol. Med.* **1960**, *103*, 304.
Pringle, W. J. S.; Moran, J. *J. Soc. Chem. Ind.* **1942**, *61*, 108.
Reinhold, J. G. *Am. J. Clin. Nutr.* **1971**, *24*, 1204.
Reinhold, J. G.; Lahimgarzadeh, A.; Nasr, K.; Hedayat, H. *Lancet* **1973**, *1*, 283.
Reinhold, J. G. *J. Am. Diet. Assoc.* **1975**, *68*, 38.
Sharpe, L. H.; Peacock, W. C.; Cooke, R.; Harris, R. S. *J. Nutr.* **1950**, *41*, 433.
Taylor, T. G. *Proc. Nutr. Soc.* **1965**, *24*, 105.
Ter-Sarkissian, N.; Azar, M.; Ghavifakr, H.; Ferguson, T.; Hedayat, H. *J. Am. Dietetic Assoc.* **1974**, *65*(6), 651.
Wheeler, E. L.; Ferrel, R. E. *Cereal Chem.* **1971**, *48*, 312.

Received for review March 25, 1985. Revised manuscript received November 4, 1985. Accepted May 5, 1986.

Amino Acid Composition of Malts: Effect of Germination and Gibberellic Acid on Hulled and Hulless Barley and Utility Wheat

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Malts of hulled barley Harrington, hulless barley Scout, and utility wheat Glenlea showed a decrease in the glutamic acid as compared to aspartic acid and lysine values, which increased with extended germination from 2 to 5 and 8 days. Inverse and statistically significant coefficients of correlation between glutamic and aspartic acids ($r = -0.72$, $P < 0.01$) and between glutamic acid and lysine values ($r = -0.78$, $P < 0.01$) were obtained. The values for proportion of total essential to total amino acids of ungerminated Harrington and Glenlea cultivars increased by 3–7% due to germination, with a negligible increase shown by the malts of hulless barley Scout. The chemical score for threonine was lower than that of lysine and isoleucine, except for the 2-day malts. A consistent increase in the score for lysine with germination was observed in all malts, except for the 2-day Scout malts.

INTRODUCTION

Amino acid composition of various cereal grains as affected by germination has been the subject of several investigations (Dalby and Tsai, 1976; Wu and Wall, 1980; Wu, 1982, 1983), emphasizing changes in essential amino acids, especially lysine. Robbins and Pomeranz (1971) studied changes in the amino acid composition of barley malts. The effect of gibberellic acid (GA) and nutritional status of malt proteins has not been studied so far. Information regarding the amino acid compositon of hulless barley cv. Scout, and utility wheat cv. Glenlea (*Triticum aestivum* L.) is not available. The hulless barley and the utility wheat cultivars are low in price and high in protein content. These are mainly used as feed grain (Crop Research '82, 1982). Their potential for malting for food purposes has been reported by Singh and Sosulski (1985). The purpose of this investigation was to study the changes in the amino acids of these cultivars as influenced by germination and GA treatment. Changes in the proportion of total essential (E) to total amino acids (T) in protein (E/T %) and chemical score (WHO, 1973) profile of essential amino acids are reported.

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MATERIALS AND METHODS

Grain samples of two-row hulled barley Harrington, hulless Scout and utility wheat Glenlea cv. were obtained from the Research Farm of the University of Saskatchewan. The samples were cleaned and stored in air-tight containers for use as desired.

Malting. A weighed sample (60 g) of each variety was steeped to 44% moisture at 15 °C changing water every

