Chapaties with Leavening and Supplements: Changes in Texture, Residual Sugars, and Phytic Phosphorus

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ABSTRACT

Yeast leavening, glycerol monostearate, and α-amylase supplements notably improved the texture and flavor of whole meal *chapaties* as compared with the traditional unleavened *chapaties*, which are tough and highly susceptible to staling. Accompanying changes due to leavening in the hydrolysis of phytates and sugars in the *chapaties* are presented. Adjusting the pH to 5.1–5.2 with lactic acid had a salutary effect on the reduction of phytates in plain and fermented dough *chapaties*.

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Wheat in India is often consumed in the form of whole meal *chapaties* (unleavened pan cakes). The traditional method of making *chapaties* from plain whole meal doughs has changed little over the years. Unless eaten immediately after baking, *chapaties* become stale and difficult to chew. This poses a serious problem, especially to geriatrics and infants. Apart from such physical constraints, wheat whole meal has a high proportion of phytic phosphorus (Bains 1949) that may bind or complex with nutritionally important minerals such as calcium, iron, and zinc (Davies and Nightingale 1975, McCance and Widdowson 1943, Oberleas 1973, Reinhold et al 1973, Sharp et al 1950). No serious attempt has been made to change the physical quality of *chapaties* by introducing yeast leavening with supplements. Information regarding the fate of phytate in unleavened whole meal *chapaties* is scanty. The present investigation was conducted to ascertain the effect of yeast leavening and supplements such as fat, sodium stearoyl-2-lactylate (SSL), glycerol monostearate (GMS), sugar, malt flour, and pH on the physical properties, residual sugars, and status of phytic phosphorus in the *chapaties*.

MATERIALS AND METHODS

Two commercially grown varieties of Indian wheats, WL 711 and WG 357, were ground into whole meal in a local power-driven stone grinder. These are high-yielding, double dwarf, spring varieties of bread wheats that have hard amber grains. They form the bulk of about 4 million metric tonnes of surplus wheat contributed by the Punjab State to India's Central Food Resources Pool. Various levels of compressed yeast (CY) and active dry yeast (ADY) were used as leavens in the preparation of dough for *chapaties*. Hydrogenated vegetable fat (mp 37°C) was used. SSL and GMS were proprietary products. Malt flour was prepared from barley malt in the laboratory and had an α-amylase activity of 33 SKB/g. Lactic acid was incorporated as an aqueous solution while the dough was mixed to obtain a pH of 5.1–5.2.

Farinograms

A Brabender farinograph fitted with a 50-g capacity stainless steel bowl was used to obtain farinograms adopting the constant flour (50 g, 14% mb) AACC method (1972). Water absorption was adjusted to center the curve on the 500 Brabender unit line. The effect of supplements on dough properties was evaluated by interpreting the curves for absorption, dough development time, and degree of softening.

Preparation of Chapaties

For leavening, CY (0.0, 0.5, 1.0, 1.5, and 2.0 g/100 g) and ADY (0.0, 0.25, 0.50, and 1.0 g/100 g) were used. The supplements (g/100 g) included sugar (1), SSL (0.25 and 0.50), fat (1), GMS (0.25 and 0.50), lactic acid (0.35), and α-amylase (0, 10, and 20 SKB/100 g.)

Dough from whole meal (100 g, 14% mb) was prepared in a mechanical mixer by adjusting the amount of water (67%, 14% mb) to produce a dough of usual consistency. Different levels of CY and ADY were incorporated in the preparation of doughs with and without sugar and various supplements. ADY was rehydrated in warm water (40°C) before use. The dough was transferred to 500-ml capacity (13 cm tall) beakers for fermentation at 30°C and 90% rh in the Baily Fermentation Cabinet. The dough expansion was recorded at half-hour intervals for 3 hr by measuring the height in centimeters. The dough was then punched manually to remove CO_2 and allowed to recover for 15 min. A dough piece (40 g) was rounded manually, rolled into circular shapes (15-cm diameter), and baked on a hot plate (350°F). In one set of experiments, doughs with adjusted pH were fermented for 3 and 6 hr, respectively, before baking.

Chapaties were evaluated for color, puffing, flavor, texture, and chewing properties. Vasculation in the *chapaties* was measured by evaluating the fourfold thickness (in centimeters) of *chapatie* disks using a vernier scale. For analysis, the *chapaties* were cut into small pieces, air-dried, and ground to fine powder in the Kamas AB Mill (Stockholm, Sweden).

Moisture, gluten, protein, ash, diastatic activity, and damaged starch contents of the whole meals were determined by AACC methods (1972). Reducing and nonreducing sugars were determined according to the AOAC methods (1975) and values expressed as maltose (anhydrous) and as percent sucrose, respectively. Total phosphorus was determined by the molybdenum blue method (Hart and Fisher 1971) and phytic P by the method of McCance and Widdowson (1935), with the modification of Snook (1938) as described by Tara et al (1971).

Nonphytic phosphorus was determined by difference. The results are expressed on 14% mb.

RESULTS AND DISCUSSION

The composition of WL 711 and WG 357 whole meal is given in Table I. The wheats had 10.3 and 10.6% protein, respectively, and fairly highly damaged starch content when made into whole meal in commercial stone grinder. As a result, the diastatic activity of the meal was fairly high. The phytic phosphorus content of WL 711 was 54.5% as compared to 48.4% of WG 357. Varietal differences were evident in the reducing and nonreducing sugar contents of the whole meal.

Farinograms

The absorption of whole meal was 69.2%. Dough development time was 5 min for WL 711 and 5.5 min for WG 357. Supplements such as fat, SSL, and GMS hardly affected the dough development time, except for slightly decreasing the consistency and dough softening values.

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Effect of Yeast Leavening and Supplements on Dough Expansion

After 3 hr, the dough without yeast showed no expansion, whereas the dough with 0.5% yeast showed considerable expansion. The increase in WL 711 was from 4.0 to 6.3 cm, as compared to the 7.6-cm increase in WG 357. When amounts of yeast were expanded to 1.0, 1.5, and 2.0 g/100 g, maximum dough expansions in WL 711 were as much as 7.2, 7.3, and 7.9 cm compared to 8.2, 8.3, and 8.4 cm in WG 357. In supplements with and without sugar, the WL 711 doughs fermented for 3 hr attained a rise of 7.1–8.0 cm, compared to 7.6–8.6 cm in WG 357. With 1.0% of ADY, the dough expansion increased to 7.6 cm, compared to 6.0 cm of dough with 0.25% yeast. The compressed yeast responded to the inclusion of sugar in dough by bringing about a greater dough expansion than was observed with ADY. The dough rise at the end of 3 hr of fermentation was 6.2–7.5 cm in WL 711 with various supplements and 7.0–7.8 cm in WG 357.

Chapaties

Compressed Yeast. Chapaties without leavening (control) appeared brown, which is characteristic of whole meal *chapaties* of amber bread wheats. The color of *chapaties* (Tables II–IV) made from fermented dough improved (expressed as yellowish to creamish-yellow, which the consumer prefers). *Chapaties* made without yeast were tough but turned soft when 0.5% CY was used and remained soft for a longer time after baking than did *chapaties* made without yeast. The fourfold thickness of WG 357 *chapaties* increased from 0.95 to 1.42 and WL 711 from 0.79 to 1.19 cm as the level of yeast was increased from 0.0 to 2.0%. Flavor of leavened *chapaties* corresponding to 1.5% yeast was pleasing, whereas those with 2.0% yeast had a yeastlike flavor. *Chapaties* with 0.5% yeast resembled unleavened control in swelling, color, flavor, and texture. Yeast levels of 1.0 and 1.5% were considered desirable for obtaining improved and soft-textured *chapaties* of both varieties.

CY and Supplements. The physical characteristics of *chapaties* made with CY (1.5 g/100 g) and supplements with and without sugar are shown in Tables II and III. *Chapaties* of WG 357 were softer and more vasculated than those of WL 711. The thickness of fourfold disks of WL 711 *chapaties* without yeast was 0.79 cm; this increased to 1.03 cm with yeast and supplements. *Chapaties* of WG 357 swelled to a greater extent, the values being 1.03 cm for control and 1.43 cm when yeast and various supplements were added to dough. With sugar in the dough, vasculation increased further, to 1.11 cm (WL 711) and 1.66 cm (WG 357). α-Amylase supplement without yeast produced tough brown *chapaties* with a vasculation value of 0.95 cm (Table IV). However, with yeast and GMS, very soft, light-textured, and slightly creamish-yellow *chapaties* were obtained. The fourfold thickness of *chapaties* of WL 711 and WG 357 was 1.19 and 1.51 cm, respectively. *Chapaties* with yeast leavening and GMS were lighter in appearance, had pleasing flavor and very soft texture and were easy to bite and chew, even when kept for considerable time after baking—up to about 12 hr in an air-tight container. When refreshed by warming on a hot plate, the fermented *chapaties* with GMS were relatively much softer than the control, even after 24 hr.

ADY and Supplements. Chapaties with 0.5 g of ADY per 100 g of whole meal were soft and fluffy, though somewhat less than those made with CY. The fourfold thickness of control *chapaties* was 1.03 cm, which increased to 1.43 and 1.51 cm in WG 357 when yeast and GMS were used with or without sugar, respectively. The swelling of *chapaties* was less pronounced with ADY than CY, as seen from the results in Tables II and III.

Residual Sugars in Chapaties. Reducing sugars expressed as maltose initially contained in whole meals of WL 711 and WG 357

TABLE I
Composition of Whole Meals of WL 711 and WG 357 Varieties of Wheat

Composition	Whole Meal WL 711	WG 357
Ash (%)	1.71	1.46
Wet gluten (%)	23.80	29.20
Protein (%) (N × 5.7)	10.30	10.60
DA[a] (mg of maltose/10 g)	342.00	432.30
DS[b] (%)	8.81	9.24
Total P (mg/100 g)	285.60	288.60
Phytic P (mg/100 g)	155.60	139.60
Reducing sugar as maltose (%)	0.33	0.53
Nonreducing sugar as sucrose (%)	2.74	3.33

[a]DA = diastatic activity.
[b]DS = damaged starch.

TABLE II
Effect of CY[a] (1.5 g/100 g), ADY[b] (0.5 g/100 g), and Supplements on the Swelling, Texture, and Color of WL 711 *Chapaties*

Supplement (g/100 g)	Fourfold Thickness of *Chapaties* (cm) CY	ADY	Texture[c] CY	ADY	Color[d] CY	ADY
Without Sugar						
Control[e]	0.79	0.79	SH	SH	B	B
Control[f]	0.95	0.95	S	S	Y	Y
Fat,[g] 1.00	0.95	0.95	VS	SH	Y	LB
SSL,[h] 0.25	0.95	1.03	VS	S	Y	LY
0.50	0.95	1.03	VS	S	Y	LY
GMS,[i] 0.25	1.03	1.11	VS	VS	LY	Y
0.50	1.03	1.11	VS	VS	CY	Y
With Sugar						
Control[e]	0.95	0.87	SH	H	B	LB
Control[f]	1.03	1.03	S	S	Y	Y
Fat,[g] 1.00	1.11	1.03	S	SH	LB	LB
SSL,[h] 0.25	1.11	1.03	S	S	Y	LY
0.50	1.11	1.11	VS	S	Y	LY
GMS,[i] 0.25	1.11	1.11	VS	VS	Y	Y
0.50	1.15	1.19	VS	VS	CY	Y

[a]CY = compressed yeast.
[b]ADY = active dry yeast.
[c]H = hard, S = soft, SH = semihard, VS = very soft.
[d]B = brown, LB = light brown, Y = yellowish, LY = light yellow, CY = creamish-yellow.
[e]Without yeast.
[f]With yeast.
[g]Hydrogenated fat.
[h]SSL = sodium stearoyl-2-lactylate.
[i]GMS = glycerol monostearate.

wheats were 0.33 and 0.53%, respectively. The values increased to 4.82 and 4.85% when baked into *chapaties* without yeast (Table V). The values decreases slightly when doughs were fermented with CY along with GMS with or without sugar, whereas with ADY, the values were more or less the same. Nonreducing sugars in whole meals of WL 711 and WG 357, expressed as sucrose, were 2.74 and 3.33%, which decreased to 1.22 and 1.29%, respectively, when baked into *chapaties*. The sugars in the *chapaties* decreased considerably when doughs were fermented with CY along with GMS, with or without sugar, whereas with ADY, reduction was less pronounced. The maltose content of *chapaties* increased considerably when 10–20 SKB of α-amylase supplements were used in the preparation of doughs (Table VI). *Chapaties* of both varieties without yeast were found to contain 7.67 and 7.55% maltose. These values decreased to 5.17 (WL 711) and 5.13% (WG 357) when CY and GMS were used in the preparation of dough for leavening. However, with ADY, a negligible decrease in the maltose values occurred because of adaptation lag for fermentation of maltose (Matz 1972). CY probably had a more effective maltase system than ADY for utilizing sugars formed by the cereal malt supplement during the process of preparing leavened *chapaties*.

pH, Fermentation Time, GMS, and α-Amylase

Chapaties made with and without CY and adjusted to pH 5.1, as compared to pH 6.1 of control, were judged normal and had no detectable acid taste or lactic acid odor. The dough expansion was normal. Extending dough fermentation from 3 to 6 hr did not improve color and texture of the *chapaties*. Considerable differences in the sugar contents of the *chapaties* occurred, depending on the duration of fermentation (Table VII). Hydrolyzable sugars, expressed as sucrose, in plain *chapaties* were higher than those in the leavened *chapaties* made with and without GMS. Reducing sugars in *chapaties* increased with the α-amylase and GMS supplements. Extending dough fermentation to 6 hr considerably depleted the free reducing sugars as compared to the *chapaties* of 3-hr fermented doughs. The *chapaties* supplemented

TABLE III
Effect of CY[a] (1.5 g/100 g), ADY[b] (0.5 g/100 g), and Supplements on the Swelling, Texture, and Color of WG 357 *Chapaties*

Supplement (g/100 g)	Fourfold Thickness of *Chapaties* (cm)		Texture[c]		Color[d]	
	CY	ADY	CY	ADY	CY	ADY
Without Sugar						
Control[e]	1.03	1.03	H	SH	B	B
Control[f]	1.35	1.51	S	S	LB	Y
Fat,[g] 1.00	1.35	1.51	S	SS	LB	CY
SSL,[h] 0.25	1.35	1.35	S	S	CY	CY
0.50	1.27	1.35	SS	S	CY	LY
GMS,[i] 0.25	1.43	1.43	VS	VS	CY	LY
0.50	1.43	1.35	VS	VS	CY	
With Sugar						
Control[e]	1.03	1.11	SH	SH	B	B
Control[f]	1.51	1.51	S	SS	LB	LB
Fat,[g] 1.00	···	1.35	SS	S	LB	LY
SSL,[h] 0.25	···	1.43	S	S	Y	LY
0.50	1.35	1.43	S	S	Y	LY
GMS,[i] 0.25	1.66	1.51	VS	VS	CY	LY
0.50	1.66	1.51	VS	VS	CY	LY

[a]CY = compressed yeast.
[b]ADY = active dry yeast.
[c]H = hard, S = soft, SH = semihard, VS = very soft.
[d]B = brown, LB = light brown, Y = yellowish, LY = light yellow, CY = creamish-yellow.
[e]Without yeast.
[f]With yeast.
[g]Hydrogenated.
[h]SSL = sodium stearoyl-2-lactylate.
[i]GMS = glycerol monostearate.

TABLE IV
Effect of CY[a] and ADY[b] with Amylase Supplement on the Swelling, Texture, and Color of *Chapaties*

Chapatie	α-Amylase (SKB)	GMS[c] (g/100 g)	Fourfold Thickness of *Chapaties* (cm)		Texture[d]		Color[e]	
			WL 711	WG 357	WL 711	WG 357	WL 711	WG 357
Without yeast	0	···	0.79	1.03	SH	SH	B	B
	10	···	0.95	0.95	H	SH	B	LB
	20	···	0.95	0.95	H	SH	B	LB
CY series	10	0.25	1.11	1.51	S	VS	LY	CY
	20	0.25	1.19	1.51	S	VS	CY	CY
ADY series	10	0.25	1.11	1.59	S	VS	LB	CY
	20	0.25	1.11	1.51	S	VS	LB	CY

[a]CY = compressed yeast; 1.5 g/100 g.
[b]ADY = active dry yeast; 0.5 g/100 g.
[c]GMS = glycerol monostearate.
[d]H = hard, S = soft, VS = very soft, SH = semi-hard.
[e]B = brown, LB = light brown, LY = light yellow, CY = creamish-yellow.

TABLE V
Effect of CY,[a] ADY,[b] and GMS[c] on the Residual Sugars in *Chapaties*

Chapatie	Sugar (g/100 g)	GMS (g/100 g)	WL 711 *Chapatie* Maltose (%)	WL 711 *Chapatie* Sucrose (%)	WG 357 *Chapatie* Maltose (%)	WG 357 *Chapatie* Sucrose (%)
Whole meal	...	...	0.33	2.74	0.53	3.33
Chapatie (control)	...	...	4.82	1.22	4.85	1.29
CY series	0.0	0.00	4.30	0.54	4.48	0.40
	0.0	0.25	4.56	0.61	4.43	0.43
	0.0	0.50	4.32	0.69	4.33	0.40
	1.0	0.00	4.68	0.58	4.55	0.89
	1.0	0.25	4.55	0.65	4.85	0.54
	1.0	0.50	4.58	0.47	4.80	0.40
ADY series	0.0	0.00	4.85	0.80	4.83	0.80
	0.0	0.25	4.77	0.91	4.65	1.09
	0.0	0.50	4.48	0.98	4.85	1.02
	1.0	0.00	5.64	0.80	5.83	0.90
	1.0	0.25	4.80	0.63	4.84	0.65
	1.0	0.50	4.85	0.54	4.65	0.47

[a]CY = compressed yeast; 1.5 g/100 g.
[b]ADY = active dry yeast; 0.5 g/100 g.
[c]GMS = glycerol monostearate.

TABLE VI
Effect of CY[a] and ADY[b] with α-Amylase Supplement on Residual Sugars in *Chapaties*

Chapatie	GMS[c] (g/100 g)	α-Amylase (SKB/100g)	WL 711 *Chapatie* Maltose (%)	WL 711 *Chapatie* Sucrose (%)	WG 357 *Chapatie* Maltose (%)	WG 357 *Chapatie* Sucrose (%)
Without yeast						
Control[d]	...	0	4.82	1.22	4.85	1.29
Control[e]	...	10	7.67	0.71	7.53	0.81
Control[f]	...	20	7.64	0.65	7.47	0.56
CY series	0.25	10	5.17	0.36	5.13	0.36
	0.25	20	5.83	0.59	5.92	0.23
ADY series	0.25	10	6.85	0.54	7.21	0.59
	0.25	20	7.38	0.56	7.37	0.63

[a]CY = compressed yeast; 1.5 g/100 g.
[b]ADY = active dry yeast; 0.5 g/100 g.
[c]GMS = glycerol monostearate.
[d]Without amylase supplement.
[e]10 SKB.
[f]20 SKB.

TABLE VII
Effect of Fermentation Time (CY,[a] 1.5 g/100 g), pH, GMS,[b] and α-Amylase Supplements on Residual Sugars in WG 357 *Chapaties*

Chapatie	Dough Rest/ Fermentation (hr)	Supplement LA[c] (%)	Supplement GMS (%)	Supplement α-Amylase (SKB/100g)	pH	Reducing Sugar as Maltose (%)	Nonreducing Sugar as Sucrose (%)
Whole meal	...	...	...	...	6.1	0.73	2.98
Chapatie (without yeast)	3	...	...	...	6.1	6.2	2.10
	6	...	...	...	6.2	6.2	1.94
	3	0.35	...	...	5.2	7.1	1.70
	6	0.35	...	...	5.2	7.0	0.94
Chapatie (with yeast)	3	0.00	0.25	0	6.0	4.14	1.20
	3	0.00	0.25	10	5.9	5.14	1.40
	3	0.35	0.25	0	5.1	3.75	1.00
	3	0.35	0.25	10	5.1	4.95	1.40
	6	0.00	0.25	0	5.8	1.21	0.82
	6	0.00	0.25	10	5.7	2.03	1.10
	6	0.35	0.25	0	5.1	1.03	0.56
	6	0.35	0.25	10	5.1	2.01	0.56

[a]CY = compressed yeast.
[b]GMS = glycerol monostearate.
[c]LA = lactic acid.

with 10 SKB units of α-amylase contained relatively more maltose. Adjusting the pH of the *chapaties* had negligible effect on the residual sugar content.

Total P, Phytic P, and Nonphytic P in *Chapaties*

Total P contents of the whole meal, and fermented and unfermented dough *chapaties* remained more or less constant (Table VIII). The phytic P contents of WL 711 and WG 357 wheats were 155.6 and 139.6 mg, respectively, which accounted for 54.5 and 48.4% of total P in the whole meals, respectively. Booth et al (1941) reported that phytic P formed 70–75% of the total P in wheat. The percentage of phytic P as reported by Bains (1949) varied between 63.0 and 76.6%, depending on the fertilizer applied to the same wheat variety. The phytic P content in the plain *chapaties* of WL 711 and WG 357 decreased to 123.5 mg. This undoubtedly indicated some hydrolysis of phytates (20.7 and 11.6%) when plain doughs of WL 711 and WG 357 were kept for 3 hr and then baked into *chapaties*. Reduction in the phytic P in the fermented dough *chapaties* was, however, considerable (Table VIII-IX). The values seemed to increase somewhat when GMS was used with or without sugar in the dough of both the varieties. A similar trend was also observed in the *chapaties* made with ADY and these supplements. However, the hydrolysis of phytic acid was relatively less than that in CY *chapaties*. Evidently, the phytase in ADY was less effective than that in CY. α-Amylase supplements (10–20 SKB/100 g) contributed little to the hydrolysis of phytates in the *chapaties*.

pH, Fermentation Time, and Phytate Hydrolysis

Adjusting the pH of the dough to 5.1–5.2 resulted in a pronounced hydrolysis of phytates in *chapaties* made with and without yeast leavening (Table X). In normal *chapaties* having a pH of 6.1, phytate was hydrolyzed to 16.0% as compared to 62.5% when pH was adjusted to 5.1. The hydrolysis was slightly higher at

TABLE VIII
Effect of Fermentation on Total P, Phytic P, and Nonphytic P in WL 711 *Chapaties*

Chapatie	Supplement		Phosphorus (mg/100 g)			Phytic P (%)	Nonphytic P (%)	Phytate Hydrolyzed (%)
	Sugar (g/100 g)	GMS[a] (g/100 g)	Total P	Phytic P	Nonphytic P			
Whole meal	···	···	285.6	155.6	130.0	54.5	45.5	···
Control[b]	···	···	291.6	123.5	168.1	42.4	57.6	20.7
CY series[c]	0.0	0.00	291.6	104.7	186.9	35.9	64.1	32.8
	0.0	0.25	291.6	85.2	206.4	29.3	70.7	45.3
	0.0	0.50	304.4	99.3	205.1	30.6	67.4	36.2
	1.0	0.00	291.6	107.4	184.2	36.8	63.2	31.0
	1.0	0.25	291.6	77.8	213.8	26.7	73.3	50.0
	1.0	0.50	285.6	83.2	202.4	29.1	70.9	46.6
ADY series[d]	0.0	0.00	297.8	115.4	182.4	38.8	61.2	25.9
	0.0	0.25	304.2	104.7	199.5	34.4	65.6	32.8
	0.0	0.50	291.6	104.7	186.8	35.9	64.1	32.8
	1.0	0.00	297.8	111.4	186.4	37.4	62.6	28.5
	1.0	0.25	296.2	104.7	191.5	35.4	64.6	32.8
	1.0	0.50	296.2	107.4	188.8	36.3	63.7	31.0

[a]GMS = glycerol monostearate.
[b]Without yeast.
[c]CY = compressed yeast; 1.5 g/100 g.
[d]ADY = active dry yeast; 0.5 g/100 g.

TABLE IX
Effect of Fermentation and Supplements on Total P, Phytic P, and Nonphytic P in WG 357 *Chapaties*

Chapatie	Supplements		Phosphorus (mg/100 g)			Phytic P (%)	Nonphytic P (%)	Phytate Hydrolyzed (%)
	Sugar (g/100 g)	GMS[a] (g/100 g)	Total P	Phytic P	Nonphytic P			
Whole meal	···	···	288.6	139.6	149.0	48.4	51.6	···
Control[b]	···	···	291.6	123.5	168.1	42.3	57.7	11.6
CY series[c]	0.0	0.00	298.2	87.3	210.9	29.3	70.7	37.5
	0.0	0.25	291.6	75.2	216.4	25.8	74.2	46.2
	0.0	0.50	294.5	83.2	211.3	28.3	71.7	40.5
	1.0	0.00	288.6	84.5	204.1	29.3	70.7	39.5
	1.0	0.25	288.6	91.2	197.4	31.6	68.4	34.7
	1.0	0.50	291.6	76.5	215.1	26.3	73.7	45.3
ADY series[d]	0.0	0.00	307.8	104.7	203.1	34.0	66.0	25.0
	0.0	0.25	294.5	110.1	184.5	37.4	62.6	21.3
	0.0	0.50	294.5	115.4	179.1	39.2	60.8	17.4
	1.0	0.00	296.2	104.7	191.5	35.3	64.7	25.0
	1.0	0.25	288.6	112.7	175.9	39.1	60.9	19.3
	1.0	0.50	291.6	118.1	173.5	40.5	59.5	15.4

[a]GMS = glycerol monostearate.
[b]Without yeast.
[c]CY = compressed yeast; 1.5 g/100 g.
[d]ADY = active dry yeast; 0.5 g/100 g.

TABLE X
Effect of Fermentation Time (Compressed Yeast, 1.5 g/100 g), pH, GMS,[a] and α-Amylase Supplements and the Phytic P and Nonphytic P Contents of WG 357 *Chapaties*

Chapatie	Dough Rest/ Fermentation (hr)	Supplement LA[b] (%)	GMS (%)	α-Amylase (SKB/100 g)	pH	Phosphorus (mg/100 g) Total P	Phytic P	Nonphytic P	Phytic P[c] (%)	Nonphytic P (%)	Phytate Hydrolyzed[d] (%)
Whole meal	...	...	...	...	6.1	310.6	157.6	153.3	50.7	49.3	...
Chapatie	3	...	...	...	6.1	318.8	132.4	186.4	41.5	58.5	16.0
(without yeast)	6	...	...	...	6.2	313.4	124.0	189.4	39.6	60.4	21.4
	3	0.35	0.00	0.00	5.2	309.1	59.2	149.9	19.1	80.9	62.5
	6	0.35	0.00	0.00	5.2	305.1	46.5	158.9	15.3	84.7	70.5
Chapatie	3	0.00	0.25	0.00	6.0	325.6	102.4	223.2	31.4	68.6	34.8
(with yeast)	3	0.00	0.25	10.00	5.9	328.9	108.4	220.5	33.4	67.0	31.3
	3	0.35	0.25	0.00	5.1	330.0	59.6	270.4	18.1	81.9	62.2
	3	0.35	0.25	10.00	5.1	319.9	64.8	255.1	20.2	79.8	58.9
	6	0.00	0.25	0.00	5.8	325.4	97.0	228.4	29.8	70.2	38.5
	6	0.00	0.25	10.00	5.7	322.2	97.0	225.2	30.1	69.9	38.5
	6	0.35	0.25	0.00	5.1	318.8	46.3	272.5	14.5	85.5	70.7
	6	0.35	0.25	10.00	5.1	324.7	50.0	174.7	15.4	84.6	68.3

[a] GMS = glycerol monostearate.
[b] LA = lactic acid.
[c] Phytic P/Total P × 100.
[d] 100 − (Phytic P in *Chapatie*/ Phytic P in Whole Meal × 100).

the adjusted pH when yeast was used as a leaven in *chapaties*. Extending fermentation time from 3 to 6 hr contributed nominally to further increase in the hydrolysis of phytates. pH adjustment close to the optimum activity of phytase action (Peers 1953, Pringle and Moran 1942) is probably vital in the effective hydrolysis of phytates in the whole meal *chapaties*. However, merely adjusting the pH had no effect on the texture of *chapaties*, which principally depended on leavening in conjunction with the supplements. Pringle and Moran (1942) studied the destruction of phytin in 85% extraction flour bread subjected to 3, 5, and 8 hr of fermentation and in which 59, 64, and 76% hydrolysis of phytin was reported. Ranhotra (1972, 1973) reported considerable hydrolysis of phytic acid by yeast in bread prepared from a wheat protein concentrate-flour blend (30:70). The sponge method of breadmaking followed by the author permitted sufficient time for the phytase action in the dough system and accompanying changes in pH. According to Reinhold (1975), decrease of phytate in 75–85% and 85–90% extraction whole meal breads prepared by the sponge method was considerable, but in 95–100% extraction whole meal breads, the decrease was much less. Higher calcium content may have been responsible for the presence of phytase inhibitor in whole meal. With increased fermentation time (from 2 to 4 hr), Harland and Harland (1980) obtained 12.5–25.0% reduction of phytates in whole wheat bread made with 0.8 to 0.9% ADY. Doubling the yeast made no further contribution to the reduction of phytates. However, sponge and sourdough methods of breadmaking are becoming out of vogue. Lactic acid is the major organic acid in processed breads (Johnson 1925). Because the amount of lactic acid used for adjusting pH was not detectable in the *chapaties*, its contribution to accelerate phytate hydrolysis is even more significant.

Changing the method of preparation of *chapaties* can improve the texture and sweetness and reduce the phytates while not detracting from the consumer acceptance of *chapaties*. Introduction of leavening and use of supplements appear feasible as means to restrain staling and to induce biochemical reduction of phytates and increase the residual sugars in the *chapaties* to make them more palatable.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1972. Approved Methods of the AACC. The Association, St. Paul, MN.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analysis. 12th ed. Method 14.023. Washington, DC.

BAINS, G. S. 1949. Effect of commercial fertilizers and green manure on yield and nutritive value of wheat. I. Nutritive value with respect to total phosphorus, phytic phosphorus, nonphytic phosphorus, and calcium content of the grain. Cereal Chem. 26:317.

BOOTH, R. G., CARTER, R. H., JONES, C. R., and MORAN, T. 1941. The nations' food. II. Cereals as food. Chemistry of wheat and wheat products. J. Soc. Chem. Ind. London 60:903.

DAVIES, N. T., and NIGHTINGALE, R. 1975. The effect of phytate on intestinal absorption and secretion of zinc, and whole body retention of zinc, copper, iron and manganese in rats. Br. J. Nutr. 34:243.

HARLAND, B. R., and HARLAND, J. 1980. Fermentative reduction of phytate in rye, white, and whole wheat breads. Cereal Chem. 57:226.

HART, F. L., and FISHER, H. J. 1971. Modern Food Analysis. Springer-Verlag, New York.

JOHNSON, A. H. 1925. Identification and estimation of the organic acids produced during bread dough and cracker dough fermentation. Cereal Chem. 2:345.

MATZ, S. A. 1972. Bakery Technology and Engineering. Avi, Westport, CT.

McCANCE, R. A., and WIDDOWSON, E. M. 1935. Phytin in human nutrition. Biochem. J. 29:2694.

McCANCE, R. A., and WIDDOWSON, E. M. 1943. Mineral metabolism on dephytinized bread. J. Physiol. London 101:304.

OBERLEAS, D. 1973. Phytates. Page 363 in: Toxicants Occurring Naturally in Foods. F. M. Strong, ed. Nat. Acad. Sci., Washington, DC.

PEERS, F. G. 1953. The phytates of wheat. Biochem. J. 53:102.

PRINGLE, W. J. S., and MORAN, T. 1942. Phytic acid and its destruction in baking. J. Soc. Chem. Ind. London Trans. 61:108.

RANHOTRA, G. S. 1972. Hydrolysis during breadmaking of phytic acid in wheat protein concentrate. J. Food Sci. 37:12.

RANHOTRA, G. S. 1973. Factors affecting hydrolysis during breadmaking of phytic acid in wheat protein concentrate. Cereal Chem. 50:353.

REINHOLD, J. G. 1975. Phytate destruction by yeast fermentation in whole wheat meals. J. Am. Diet. Assoc. 66:38.

REINHOLD, J. G., NASR, K., LAHIMGARZADEH, A., and HEDAYAT, H. 1973. Effects of purified phytate and phytate-rich bread upon metabolism of zinc, calcium, phosphorus and nitrogen in man. Lancet 1:283.

SHARP, L. M., PEACOCK, W. C., COOKE, R., and HARRIS, R. S. 1950. The effect of phytate and other food factors on iron absorption. J. Nutr. 41:433.

SNOOK, L. C. 1938. Cereal grains as a source of nutritionally useful phosphorus. Emp. J. Exp. Agric. 6:20.

TARA, K. A., USHA, M. S., PRABHAVATI, C., and BAINS, G. S. 1971. Vitamin, mineral, colour grade and limiting amino acid content of Indian commercial flours. Res. Ind. 16(3):196.

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