ELSEVIER

Food Chemistry 68 (2000) 185–190

Food Chemistry

www.elsevier.com/locate/foodchem

Indian wheat cultivars: their carbohydrate profile and its relation to tandoori roti quality

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Received 9 September 1998; received in revised form 22 June 1999; accepted 22 June 1999

Abstract

Tandoori roti, a wheat-based Indian traditional product, prepared by sheeting the whole wheat flour dough into 2–3 mm thickness and 15–20 cm diameter, is baked in a special type of oven known as a 'tandoor'. Six commercially-grown wheat varieties were evaluated for their physico-chemical characteristics and carbohydrate profiles. Rheological studies indicated a significant difference among the varieties, especially between varieties having good (Cpan-3004: Sensory score, 28.27) and poor (PBW-138: Sensory score, 23.22) tandoori roti-making quality. The peak viscosity correlated well with the damaged starch content. The carbohydrate profiles of wheats indicated that the water soluble polysaccharides and destarchified flour fractions contained mainly arabinose and xylose along with glucose. The contents of arabinose and xylose were higher in the fractions of the variety having good tandoori roti-making quality.

1. Introduction

In India, wheat is one of the daily staples, consumed in the form of different flat breads such as chapati, paratha, phulka, tandoori roti, etc. Tandoori roti is served in restaurants, hotels, industrial canteens and home, and is gaining popularity in the continents of Asia and Europe. It is prepared from a dough made by kneading flour (92–100% extraction rate), water (70–75%) and salt (0.5–1.5%) and forming it into a disc of 2–3 mm thickness, 15–20 cm diameter and 50–60 g weight. Then it is baked in a special type of oven known as a 'tandoor', which is an in-ground oven consisting of an earthen pot surrounded by bricks and heated by burning coal. The flattened dough is placed onto the pre-heated inner walls of the tandoor and allowed to bake for 37 s at $425 \pm 5°C$ (Saxena, Rao & Raghava Rao, 1995).

Wheat and flour purchasers require a sound basis for economic decisions and wheat-breeding programmes require clear guidelines for selection criteria. Further, many tests are used to describe the suitability of flour for the production of a particular end-product (Bushuk, 1985; Faridi, Finney & Rubenthaler, 1982; Fifield, Weaver & Hayes, 1950; Finney & Barmore, 1948; Quail, McMaster & Wootton, 1991). Qualitative and quantitative patterns of protein are the major factors accounting for variation in loaf volume of bread within wheat varieties (Pomeranz, 1987). Qarooni, Bequette and Deyoe (1994) worked on different US hard white wheats, their effect on flour characteristics and quality of pan bread, tortilla and Arabic bread.

Arabinoxylans present in wheat have generated a lot of interest because of their role in bread-making quality (Cleemput, Roels, Oort, Grobet & Delcour, 1993; Crowe & Rasper, 1988; D'Appolonia, 1971; Rouau & Moreau, 1993; Shogren, Shashimoto & Pomeranz, 1987; Vanhamel, Cleemput, Decolour, Nys & Darius, 1993). In addition, they are proven to have significant influence on water-balance of dough (Jelaca & Hlynka, 1971; Patil, Tsen & Lineback, 1975), rheological properties of dough (Meuser & Suckow, 1986; Michniewicz, Biliaderis & Bushuk, 1991), retrogradation of starch (Biliaderis & Izydorczyk, 1992; Gudmundsson, Eliassun, Bengtsson & Aman, 1991), and bread making quality (McCleary, 1986; Delcour, Vanhamel & Hoseney, 1991).

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0308-8146/99/$ - see front matter
PII: S0308-8146(99)00174-0

The purpose of this investigation is to study the carbohydrate profile of wheat varieties differing in tandoori roti-making quality. Such information helps to predict suitability of wheat for tandoori roti preparation.

2. Materials and methods

2.1. Materials

Six commercially grown wheat varieties, viz; PBW-154, PBW-175. PBW-299, PBW-138, WL-1562 and Cpan-3004 from the 1994 crop were procured from the PAU Regional Research Station, Ropar (Punjab) and selected for study. The samples were milled to flours of 100% extraction in a Hammer mill (Kamas-Slaggy) using a 0.8 mm sieve. All flours were stored in air-tight containers at 3–4°C until studied.

2.2. Physical and chemical characteristics

The moisture, ash, hectolitre weight, 1000 kernel weight, grain hardness, Falling number and damaged starch were determined by AACC methods (AACC, 1983).

2.3. Pasting characteristics

The pasting behaviour of whole wheat flours was determined using a Newport Scientific Rapid Visco Analyser (Model RVA-3D, Sydney, Australia). The system consists of an external computer linked to the RVA fitted with a cooling water supply. A software program, thermocline, controls all the functions of the RVA by signals from the computer. The initial temperature was set at 50°C with a hold period of 1 min and heating rate was kept at 3°C per min in two independent cycles (heating and cooling). The RVA studies were carried out using a 3 g sample (on 14% m.b.) with 25 ml water.

2.4. Isolation of water-soluble polysaccharides and destarchified flour

The flour was mixed with 70% aqueous ethyl alcohol (40 ml for 10 g sample) and refluxed for 3 h. The residue obtained after centrifugation was again extracted with 70% ethyl alcohol, 3–4 times. To the alcohol-insoluble residue was added about 250 ml water and kept in a boiling water bath for about 20 min. Termamyl (heat-stable amylase, 0.5 ml) was added to the residue and the digestion was done until the residue was negative to starch by I_2-KI test. The digest was centrifuged (5000 *g*, 10 min) and the supernatant after dialysis and lyophilization gave water-soluble polysaccharides, while the residue was dried by solvent exchange to get destarchified flour (Swamy, Ramakrishnaiah, Kurien & Salimath, 1991).

2.5. Hydrolysis of destarchified flour

The sample (20 mg) was allowed to swell overnight in water (0.28 ml) at room temperature. To this, 0.72 ml of conc H_2SO_4 was added in small aliquots to solubilize the sample, while keeping the test tube at ice-cold temperature. Then the volume was made up to 1 N H_2SO_4 by adding the required amount of distilled H_2O and samples were hydrolysed in a boiling water bath with an air condenser for 4 h. After cooling, 1 ml of solution was taken for total carbohydrate and uronic acid estimations and the rest of it was neutralised using solid barium carbonate. After filtration, the filtrates were deionised with Amberlite IR-120 (H+) resin and concentrated for PC/GLC analyses (Swamy et al., 1991).

2.6. Hydrolysis of water-soluble polysaccharides

The samples (10 mg) were hydrolysed with trifluoroacetic acid (1 N, 1 ml) in sealed tubes at 100°C for 4 h. After cooling. the tubes were opened and flash-evaporated repeatedly (1 ml, ×5) with water until the samples became neutral. Then these were taken for PC/GLC analyses.

2.7. Analytical methods

The contents of total carbohydrates and uronic acid were estimated by the phenol-sulfuric acid (Dubois, Gilles, Hamilton, Rebers & Smith, 1956) and carbazole (Bitter & Muir, 1962; Dische, 1947) methods, respectively. Identification of sugars by paper chromatography was done using Whatman No. 1 chromatographic paper, using the *n*-butanol:pyridine:water; 6:4:3 solvent system. The chromatograms were visualised with aniline-phthalate reagent. Gas–liquid chromatography of sugars was done as alditol acetates on a Shimadzu model GC-15 A chromatograph, with flame ionization detector. A stainless steel column (1/8″×6″) packed with 3% OV-225 (column temperature, 200°C; injector temperature, 220°C and detector temperature, 250°C) was used for analysis. Flow rate of nitrogen was 15 ml/min.

2.8. Preparation of tandoori roti

Dough for tandoori roti was made by mixing whole wheat flour (100 g), salt (1.2 g) and water (variable) in a Hobart mixer (model N-50) for 4.5 min at low speed. The water required for obtaining the desired consistency dough was determined by using the farinograph (Saxena, 1997). The dough was rested for 30 min for proper hydration and then 55 g of the dough was sheeted to a circular shape using a rolling pin to a thickness of 2.5 mm. The sheeted dough was baked in a tandoori oven maintained at 425°C for 37 s (Saxena). The roties were cooled and transferred to a polyethylene pouch till further evaluations.

2.9. Evaluation of tandoori roti

2.9.1. Objective evaluation

The shear value of roti was determined by measuring the force required to shear a piece (3×8 cm^2) of roti using an Instron Universal Testing Machine (Model 4301) under the following conditions: load cell, 500 kg; plunger speed, 100 mm/min; cutter, V type. Data are averages of quadruplicate determinations.

2.9.2. Organoleptic evaluation

A 12 member taste panel judged the external and internal characteristics of tandoori roti. The fresh samples were delivered to the panellists within an hour after baking (Saxena, 1997).

2.9.3. Statistical evaluation

Statistical analyses were performed as described by Steel and Torrie (1960).

3. Results and discussion

3.1. Grain quality

The analytical data of different varieties of wheat grain are shown in Table 1. Cpan-3004 had the lowest ash content (1.41%). Test weight (1000 kernel weight) varied from 34.78 to 54.65 g and was highest for Cpan-3004. Hardness of wheat was lowest (10 kg) in PBW-138 and highest in Cpan-3004 (24 kg). The falling number of all samples was quite high (> 350 s) indicating that all samples were sound and free from weather damage. Damaged starch content ranged from 5.65 to 8.01% which was highest in good roti-making quality wheat, Cpan-3004.

3.2. Pasting characteristics

Flour starch properties were reported to have a significant effect on the quality of final product (Qarooni et al., 1994). It is evident from Fig. 1 that there are significant differences in the peak viscosities, hot paste viscosities and cold paste viscosities of flours from different wheat varieties. The peak viscosity increased with increase in damaged starch content and decrease in Falling number (Table 1). The highest value of 200 SNU was found for variety Cpan-3004. A significant difference was found for hot paste viscosity (ranging from 60 to 108 SNU) and cold paste viscosity (ranging from 131 to 226 SNU) among the varieties.

3.3. Carbohydrate composition of fractions of flour

The carbohydrate composition of whole wheat flours and their water-soluble and destarchified fractions is given in Tables 2–4. Total sugar content in the whole wheat flour of different varieties ranged from 71.9 to 88.8% and the maximum content was found in Cpan-3004 variety. The total sugar content in the water-soluble

Table 1
Physical and chemical characteristics of different wheat varieties[a–c]

Characteristics	Varieties						
	PBW-138	PBW-175	PBW-299	PBW-154	WL-1562	Cpan-3004	SEM (df = 23)
1. Moisture (%)	10.52c,d (0.18)	10.58c,d (0.14)	10.01b (0.05)	9.70a (0.05)	10.85d (0.07)	10.39b,c (0.17)	± 0.59
2. Hectolitre weight (kg/hl)	78.37a (0.49)	79.10a (0.42)	80.20b (0.52)	80.70c,d (0.54)	80.50b,c (0.39)	81.40d (0.37)	± 2.13
3. 1000 kernel weight (g)	34.78a (0.35)	42.55b (0.40)	43.53c (0.41)	44.30c (0.51)	48.50d (0.49)	54.65e (0.43)	± 1.35
4. Hardness (kg)	10.00a (0.65)	16.00b (0.77)	18.00c (0.69)	18.00c (0.68)	19.00c (0.81)	24.00d (0.62)	± 1.02
5. Ash (%)	1.73d (0.05)	1.61c (0.04)	1.58b,c (0.06)	1.63c (0.05)	1.54b,c (0.06)	1.41a (0.06)	± 0.51
6. Damaged starch (%)	5.65a (0.33)	6.02a (0.35)	6.94b (0.36)	7.30b,c (0.35)	7.33b,c (0.26)	8.01c (0.17)	± 0.32
7. Falling number (s)	443d (1.29)	438d (1.10)	440d (1.37)	418c (1.18)	405b (1.23)	392a (1.41)	± 2.12

[a] Means followed by different letters in the same row differ significantly ($P < 0.05$).
[b] Number in the parentheses denotes the standard deviation.
[c] All values are averages of four determinations.

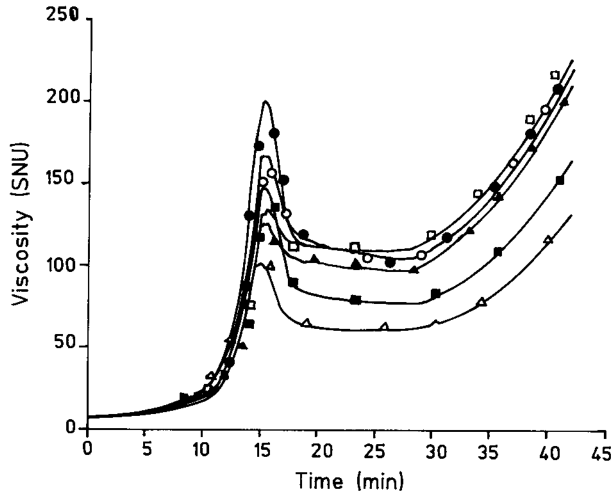

Fig. 1. Effect of varietal factors on the pasting characteristics. ● Cpan-3004, ○ WL-1562, ■ PBW-154, ○ PBW-299, ▲ PBW-175, △ PBW-138.

Table 2
Carbohydrate composition (%) of total flour[a–c]

Variety	Total sugar	Uronic acid	Arabinose	Xylose	Glucose
PBW-138	77.74b (0.82)	6.18a (0.23)	8.99d (0.83)	Tr	91.0d (1.01)
PBW-175	84.1c (0.95)	7.84b (0.51)	Tr	Tr	100c (0.90)
PBW-299	88.4d (0.68)	6.47a (0.43)	5.89c (0.26)	5.06c (0.12)	89.1b (0.75)
PBW-154	71.9a (0.79)	5.99a (0.24)	2.89a (0.47)	1.31a (0.06)	95.8e (0.98)
WL-1562	78.3b (0.82)	7.37b (0.64)	2.78a (0.48)	2.65b (0.09)	94.6d (1.06)
Cpan-3004	88.8d (1.02)	6.34a (0.46)	3.62b (0.13)	1.28a (0.01)	86.1a (0.88)
SEM (df = 17)	0.214	±0.341	±0.248	±0.198	±0.301

[a] Means followed by different letters in the same column differ significantly ($P < 0.05$).
[b] Number in the parentheses denotes the standard deviation.
[c] All values are averages of three determinations.
Tr = Trace.

Table 3
Carbohydrate composition (%) of water-soluble fraction of flour

Variety	Total sugar	Uronic acid	Arabinose	Xylose	Glucose
PBW-138	56.6b (0.52)	4.71a (0.32)	7.55a (0.86)	7.14a (0.50)	85.3d (0.91)
PBW-175	50.8a (0.94)	5.47b (0.54)	9.53b (0.75)	7.01a (0.55)	83.5c (0.83)
PBW-299	58.0c (1.68)	4.59a (0.39)	8.15a (0.56)	6.94a (0.32)	84.9d (0.91)
PBW-154	62.1d (0.89)	5.48b (0.83)	7.94a (0.70)	6.33a (0.55)	85.7d (0.83)
WL-1562	66.0e (0.62)	4.02a (0.38)	9.70b (0.88)	13.1b (0.86)	77.2b (0.82)
Cpan-3004	51.2a (0.82)	4.20a (0.26)	16.5c (0.43)	18.4c (0.58)	65.1a (0.57)
SEM (df = 17)	±0.328	±0.215	±0.207	±0.354	±0.412

[a] Means followed by different letters in the same column differ significantly ($P < 0.05$).
[b] Number in the parentheses denotes the standard deviation.
[c] All values are averages of three determinations.

Table 4
Carbohydrate composition (%) of destarchified flour[a–c]

Variety	Total sugar	Uronic acid	Arabinose	Xylose	Glucose
PBW-138	65.0c (0.88)	3.76b,c (0.21)	33.1b (0.65)	24.0b (1.42)	42.9d (0.99)
PBW-175	64.68b,c (0.75)	2.91a,b (0.31)	28.7a (0.35)	33.5d (0.51)	37.8b (0.80)
PBW-299	65.6c (0.84)	4.02c (0.47)	28.9a (0.65)	34.1d (0.53)	37.0b (1.01)
PBW-154	60.9a (0.63)	3.52b,c (0.44)	32.4b (0.62)	26.4c (0.64)	41.2c (0.89)
WL-1562	68.0d (0.83)	2.49a (0.46)	33.2b (0.67)	22.4a (0.77)	44.4e (1.86)
Cpan-3004	64.1b (0.59)	3.50b,c (0.36)	38.0c (0.72)	39.1e (0.88)	22.9a (0.86)
SEM (df = 17)	±0.234	±0.402	±0.149	±0.239	±0.167

[a] Means followed by different letters in the same column differ significantly ($P < 0.05$).
[b] Number in the parentheses denotes the standard deviation.
[c] All values are averages of three determinations.

fraction of flour ranged from 50.9 to 66.0% while in the destarchified fraction, it ranged from 60.9 to 68.0%. It was observed that WL-1562 variety had maximum carbohydrate content both in water-soluble and destarchified flours (66 and 68%, respectively). Although some difficulty was encountered in the estimation of uronic acid with the carbazole-H_2SO_4 procedure of Dische (1947), as modified by Bitter and Muir (1962) due to interference by neutral sugars, the results indicated that uronic acid comprised about 5% or less of the polysaccharide in both the fractions of the flour while in whole wheat flour it ranged from 5.99 to 7.84%. Uronic acid was identified as galacturonic acid by paper chromatography.

The whole wheat flour and its fractions were hydrolysed, reduced and their alditol acetate derivatives prepared. Their identities and relative properties of sugars were determined by GLC. Arabinose, xylose and glucose were the main constituent sugars (Tables 2–4).

Highest arabinose content was observed in PBW 138 variety, 8.99%. The same variety had xylose in trace amounts and maximum xylose content was found in the Cpan-3004 variety. The glucose content ranged from 86.1 to 100% and the minimum was found for the Cpan-3004 variety. However, no conclusion could be drawn from these figures relating to tandoori roti quality.

Cpan-3004 variety, followed by WL-1562, had arabinose and xylose in major amounts in both water-soluble and destarchified fractions of whole wheat flour. The higher amount could be mainly due to arabinoxylan type polysaccharides or may also be due to a mixture of arabinan and xylan types of polysaccharides. Glucose was found in the range of 23–45% in destarchified flour and 65–86% in water-soluble fractions of flour. The higher amount of glucose could be due to small amounts of one or more of any of the following combinations: unhydrolysed starch, water-soluble glucans and cellulose (Swamy et al., 1991).

3.4. Quality of tandoori roti

It is evident from Table 5 that the sensory panel judged the best quality roti to be the Cpan-3004 variety, having an overall quality score of 28.27, while the lowest score was observed for PBW-138, having 23.22. The shear force was found in inverse relation to the sensory score of roti and the lowest value of 40.14 N was obtained for the good roti-making quality wheat, Cpan-3004.

3.5. Inter-relationship between sensory score, shear value and carbohydrate fractions of flour

Table 6 shows a good correlation between sensory score and shear value ($R^2 = -0.95$). Also good correlations were observed between sensory score and arabinose in destarchified and water-soluble fractions of flours, and xylose in water-soluble fractions having coefficients of 0.76, 0.84 and 0.89, respectively. However, the xylose content in destarchified flour did not correlate well with sensory score ($R^2 = 0.39$). These results indicated that arabinoxylans play an important

Table 6
Correlation coefficient between sensory score of Tandoori roti and its shear value and carbohydrate composition of wheat cultivars

Variants	Correlation coefficient[a]
1. Sensory score vs shear value	−0.95 ($P < 0.05$)
2. Sensory score vs arabinose in destarchified flour	0.76 ($P < 0.05$)
3. Sensory score vs arabinose in water-soluble fraction	0.84 ($P < 0.05$)
4. Sensory score vs xylose in water-soluble fraction	0.89 ($P < 0.05$)
5. Sensory score vs xylose in destarchified flour	0.39 (NS)

[a] Correlation coefficient calculated as described by Steel and Torrie (1960).
NS, not significant.

Table 5
Effect of different wheat varieties on the quality of tandoori roti

Characteristics	Varieties						
	PBW-138	PBW-175	PBW-299	PBW-154	WL-1562	Cpan-3004	SEM
Shear value (N)	64.12a (1.15)	61.37b (1.51)	58.76c (1.25)	51.47d (1.61)	42.14e (1.01)	40.14f (1.01)	±0.624
Sensory quality							
Colour	4.67a (0.41)	4.67a (0.35)	4.67a (0.51)	4.67a (0.38)	4.77a (0.46)	4.88a (0.39)	±0.218
Appearance	4.14a (0.36)	4.24a (0.43)	4.08a (0.48)	4.17a (0.52)	4.24a (0.46)	4.53a (0.37)	±0.453
Handfeel	3.67a (0.25)	4.33b,c (0.37)	4.21b (0.46)	4.01a,b (0.50)	4.02a (0.37)	4.73c (0.35)	±0.559
Texture	3.81a,b (0.25)	3.33a (0.26)	3.83a,b (0.31)	4.04b (0.36)	4.33b,c (0.51)	4.67c (0.37)	±0.279
Mouthfeel	3.79a (0.24)	4.17a,b (0.32)	3.83a (0.23)	4.33b (0.30)	4.49b,c (0.42)	4.72c (0.25)	±0.354
Taste and flavour	3.14a (0.41)	3.04a (0.26)	4.08b (0.28)	4.17b (0.27)	4.47b,c (0.34)	4.74c (0.33)	±0.368
Overall quality (Max. 30)	23.22a	23.78a,b	24.70b,c	25.39c,d	26.30d	28.27e	±1.427

[a] Means followed by different letters in the same row differ significantly ($P < 0.05$).
[b] Number in the parentheses denotes the standard deviation.
[c] The values are averages of four determinations.

role in tandoori roti-making quality in wheat. Characterisation of arabinoxylans in these varieties is necessary to decipher the attributes of arabinoxylans for tandoori roti-making quality.

Acknowledgements

The first author (DCS) wishes to acknowledge the Senior Research Fellowship provided by the CSIR (India).

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