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Effect of Added Arabinoxylans Isolated from Good and Poor Chapati Making Wheat Varieties on Rheological Properties of Dough and Chapati Making Quality

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ABSTRACT

Arabinoxylans are the major non-starch polysaccharides in wheat and are reported to influence quality of bakery products. Arabinoxylans were isolated from good and poor chapati making varieties, added them at different levels (0.25 and 0.5 g/100g) to the same flour, interchanged with other varieties and determined the effect of arabinoxylans on rheological properties of dough and chapati making quality. Rheological properties were improved upon adding isolated arabinoxylans of good chapati making varieties to flours. Interestingly, addition of isolated arabinoxylans of good chapati making varieties to poor chapati making varieties had significantly improved the chapati quality. Sensory studies showed that chapatis prepared from flour added with arabinoxylans of good chapati varieties had soft texture and high overall quality scores. These changes are attributed to differences in their arabinose/xylose ratio. Thus, results indicated that addition of isolated arabinoxylans of good chapati making flour improved the chapati quality of poor chapati making flour.

Keywords: Wheat; Arabinoxylans; Rheology; Chapati

1. Introduction

Wheat (*Triticum aestivum*) is a major cereal crop used for the preparation of bakery products such as bread, biscuits and cakes all over the world. However, in India, about 75% of the wheat grown is used for the preparation of chapati, an unleavened flat bread, which is prepared from whole wheat flour. Chapati is the main traditional wheat based food, consumed by majority of the population in Indian subcontinent and also widely consumed in UK and other countries by Asian ethnic community [1]. The desired sensory quality characteristics of chapati are greater pliability, soft texture, light creamish brown colour, slight chewiness and baked wheat aroma [2]. Carbohydrate is the major component present in whole wheat flour and among the carbohydrates, starch is the major component and arabinoxylan is the minor component [3]. Arabinoxylans contents vary from 5 to 8% of the whole grain flour [4] while in refined wheat flour its content is very low (2% - 3%).

Arabinoxylans are also referred to as pentosans and they are the major non-starch polysaccharides present in wheat [5]. Due to their high water binding capacity water soluble arabinoxylans are known to play an important role in rheological properties of dough [6], retrogradation of starch and breadmaking quality [7,8]. Addition of water soluble arabinoxylans to refined wheat flour significantly increased the farinograph water absorption and dough development time and also increased bread quality parameters like loaf volume, crumb structure and decreased staling characteristics [9,10].

Although considerable work has been reported with respect to the role of arabinoxylans on bread quality, no reports are available with respect to whole wheat flour products such as parotta, chapati, roti, etc. Therefore, the present work was undertaken to study the effect of added water soluble arabinoxylans from good and poor chapati making wheat varieties on rheological properties of dough and chapati making quality.

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2. Materials and Methods

2.1. Wheats

Four *Triticum aestivum* wheat varieties namely DWR-162 and DWR-39, were procured from University of Agricultural Sciences, Dharwad, India and HD-2189 and MACS-2496 were procured from Agharkar Research Institute, Pune, India. DWR-162 and DWR-39 were reported as good varieties for chapati making property, while HD-2189 and MACS-2496 were poor varieties for chapati making property [11]. Wheat was milled in a commercial disc mill to obtain whole wheat flour (≤400 μ).

2.2. Isolation of Arabinoxylans

Arabinoxylans from whole-wheat flour of different wheat varieties were isolated according to the method described by Santos *et al.* [12]. Whole-wheat flours were fractionated into starch, gluten and water-solubles [13]. Water-soluble arabinoxylans were isolated and purified. The arabinoxylans present in the water solubles were precipitated from the supernatant at 80% ethanol. The precipitate was then washed and dried by exchange of solvents, followed by drying at 30˚C [14,15].

2.3. Analytical Methods

Estimation of total sugars was carried out according to the method described by Dubois *et al.* [16] and uronic acids were estimated according to the method described by Dische [17]. Sugar composition in the flour and water-insoluble fractions were analysed after solubilization with 72% sulphuric acid (in ice-cold temperature) followed by hydrolysis in 10% sulphuric acid at boiling water bath temperature for 6 - 8 h. The water-soluble fractions were hydrolysed with 2N trifluroacetic acid in sealed tubes at 100˚C for 5 - 6 h. The sugars were analysed by gas liquid chromatography as alditol acetates [18] on OV-225 column at column temperature at 200˚C using Shimadzu GLC. Arabinoxylan content was determined according to the method described by Albaum and Umbreit [19].

2.4. Rheological Characteristics

Farinograph characteristics of whole wheat flours were determined according to AACC [20] method using Brabender Farinograph-E (Brabender OHG, Duisburg, Germany). Whole wheat flours were enriched with 0.25 g/100g and 0.5 g/100g of water soluble arabinoxylans and their farinograph characteristics were studied.

The amylograph characteristics of whole wheat flours were determined using Micro Visco Amylograph (Brabender OHG, Duisburg, Germany). Whole wheat flours were enriched with 0.25 g/100g and 0.5 g/100g of water soluble arabinoxylans and their amylograph characteristics were studied. Whole wheat flours (15 g on 14% moisture basis) were suspended in 100 ml of distilled water and heated in the visco-amylograph from 30˚C to 92˚C at a rate of 5˚C/min, held at 92˚C for 5 min, cooled to 50˚C and then held at 50˚C for 1 min under constant stirring (250 rpm). Torque measuring range was 300 cmg. The viscosity was expressed in Brabender Units (BU).

2.5. Chapati Making Quality

Chapatis were prepared by adding water soluble arabinoxylans to whole wheat flour. Control chapati was prepared without addition of water soluble arabinoxylans. Chapati dough was prepared by mixing 200 g flour and water equivalent to chapati dough water absorption in a Hobart mixer (Model N-50) at speed 1 (61 rpm) for 3 min and rested for 20 minutes according to Haridas Rao *et al.* [1]. The sheeted dough (1.5 mm) was cut into a circular shape of 15 cms diameter using a die and the cut dough was baked on a hot plate at 215˚C for 70 s on side 1 and 85 s on side 2. The chapati was then transferred to a heated gas tandoor oven (370˚C) in such a way that side 1 was placed on the grill and heated for 10 s. Height of the puffed chapati was measured as soon as the chapati was removed from the tandoor oven according to Haridas Rao *et al.* [1]. The puffed chapati was then cooled, packed in polypropylene pouches and stored at room temperature until further use.

2.6. Objective and Subjective Evaluation of Chapati

The texture of chapati was evaluated by using the texture analyzer (Stable Micro Systems, Model TA-HD, UK) using the Warner Bratzler blade (HDP/BSW). Three strips measuring 5 × 2.5 cm from each chapati were cut. One strip at a time was placed on the centre of the sample holder and allowed the blade to cut the chapati strip. The force (N) required to cut the chapati strip into 2 pieces was recorded. The cross-head speed was maintained at 100 mm/min. Measurement for four chapatis were recorded and average value was reported.

A panel of ten experienced judges carried out the sensory evaluation of chapatis. The product was evaluated for color and appearance (colour of the spots and their uniformity), tearing strength, pliability and mouthfeel (soft, tough, leathery), taste and aroma (sweetish, wheat, and bland) and overall quality (sum of all the attributes). The panellists were asked to provide the scores on the basis of the quality description given against each sensory attribute evaluated.

2.7. Statistical Analysis and Graphical Representation

The experimental data, including sensory scores of chapati, were treated statistically by Duncan's new multiple range test (DMRT) to determine the significance ($p \leq 0.05$) of results [21].

3. Results and Discussion

3.1. Composition of Whole Wheat Flour

Chemical characteristics and carbohydrate profile of DWR-162, DWR-39, HD-2189 and MACS-2496 whole wheat flours are given in **Table 1**. Damaged starch contents were high in DWR-162 and DWR-39 wheat varieties, whereas the protein content is low compared to MACS-2496 wheat varieties. The falling number of HD-2189 and MACS-2496 wheat flours are high (664 and 577) indicating that it has low α-amylase activity compared to the other two whole wheat flours. The SDS sedimentation values were high for DWR-162 and DWR-39 flours indicating that the whole wheat flours are strong compared to HD-2189 and MACS-2496 whole wheat flours. However, the carbohydrate content varied from 71 to 76 g/100g in the whole wheat flours. The arabinoxylan contents of DWR-162 and DWR-39 wheat varieties were 4.7 g/100g and 4.1 g/100g, respectively, which were higher than the other two varieties (3.0 and 3.2 g/100g). The arabinose-xylose ratios of DWR-162 and DWR-39 wheat varieties were high indicating that it might be due to higher degree of branching in these arabinoxylans. Higher degree of branching was reported in few Canadian wheat flours of variable bread making quality [8]. The arabinose-xylose ratios (A/X) of HD-2189 and MACS-2496 wheat varieties were low indicating that it might be due to lower degree of branching in these arabinoxylans [22].

3.2. Composition of Isolated Arabinoxylans

The arabinoxylans isolated from DWR-162 and DWR-39 whole wheat flours were high compared to the arabinoxylan isolated from HD-2189 and MACS-2496 whole wheat flours (**Table 1**). The isolated arabinoxylans were lesser than the native arabinoxylan contents in whole wheat flours. The total sugar content of isolated arabinoxylans varied from 82.7 to 88.5 g/100g. The arabinose-xylose ratios of arabinoxylans isolated from DWR-162 and DWR-39 wheat varieties which are known to have good chapati making property were high (1.7) indicating that it might be due to higher degree of branching in these arabinoxylans. Saxena *et al.* [23] have also reported that the contents of arabinose and xylose were higher in the polysaccharide fractions of varieties of wheat that have good tandoor roti-making quality. The arabinose-xylose ratios of arabinoxylans isolated from HD-2189 and MACS-2496 wheat varieties were low (0.95) indicating that it might be due to lower degree of branching in these arabinoxylans.

3.3. Effect of Arabinoxylans on the Farinograph Characteristics of Whole Wheat Flour

3.3.1. Effect of Arabinoxylans on the Same Variety of Whole Wheat Flour

Arabinoxylans isolated were added at 0.25 and 0.5 g/100g in the same variety of whole wheat flour and farinograph characteristics of the same were studied (**Table 2**). Water absorption (WA) increased from 77.8 to 80% and 82.2% in DWR-162 flour while the increase in WA was from 75.5% to 77.5% and 80.5% in DWR-39 flour on addition of 0.25 and 0.5 g/100g arabinoxylans of the same variety, respectively. The increase in WA was 2.0% to 5% for these two good chapati making variety flours, whereas only 0.3% to 0.6% increase in WA was observed for poor chapati making quality flours obtained from HD-2189 and MACS-2496 varieties. Dough development time (DDT) decreased from 3.7 to 3.3 and 3.2 min for DWR-162 flour while the decrease in DDT was from 3.9 to 3.6 and 3.4 min for DWR-39 flour on addition of 0.25 and 0.5 g/100g arabinoxylans of the same variety, respectively. The decrease in DDT was 0.3 to 0.5 min for these two good chapati making variety whole wheat flours, whereas only 0.1 to 0.2 min decrease in DDT was observed for poor chapati making quality

Table 1. Chemical characteristics of whole wheat flour (WWF) and isolated arabinoxylans.

Wheat Varieties	Moisture (g/100g)	Damaged Starch (g/100g)	Protein (g/100g)	Falling Number (sec)	SDS Sedimentation Value (ml)	Arabinoxylan content (g/100g)	Total Sugar (g/100g)	Isolated arabinoxylans		A/X Ratio*	
								Yield in WWF (g/100g)	Total Sugar (g/100g)	WWF	Isolated Arabinoxylan
DWR-162	$7.2^b \pm 0.1$	$17.1^b \pm 0.1$	$12.7^b \pm 0.2$	$420^d \pm 11$	$59^b \pm 1$	$4.7^a \pm 0.2$	$75.2^b \pm 0.3$	3.0	$86.3^b \pm 0.7$	1.24	1.69
DWR-39	$7.3^b \pm 0.2$	$17.6^a \pm 0.3$	$12.3^c \pm 0.3$	$461^c \pm 8$	$62^a \pm 2$	$4.1^b \pm 0.1$	$74.4^b \pm 0.2$	3.0	$82.7^c \pm 0.4$	1.25	1.7
HD-2189	$7.6^a \pm 0.1$	$15.8^c \pm 0.3$	$11.8^c \pm 0.2$	$664^a \pm 12$	$50^c \pm 2$	$3.0^c \pm 0.5$	$76.1^a \pm 0.95$	2.3	$84.8^b \pm 0.5$	0.72	0.94
MACS-2496	$6.7^c \pm 0.2$	$12.3^d \pm 0.1$	$14.6^a \pm 0.5$	$577^b \pm 14$	$53^d \pm 2$	$3.2^c \pm 0.2$	$71.2^c \pm 0.2$	2.0	$88.5^a \pm 0.5$	0.91	0.96

Data reported are expressed as mean ± SD; Means followed by different letters in the same column differ significantly ($p \leq 0.05$); *A/X Ratio is arabinose to xylose ratio.

Table 2. Rheological characteristics of whole wheat flour on addition of isolated arabinoxylans.

Wheat Varieties	Variations (Arabinoxylans)	Farinograph Characteristics				Amylograph Characteristics			
		Water Absorption (%)	Dough Development Time (min)	Dough Stability (min)	Tolerance Index (BU)	Pasting Temperature (˚C)	Peak Viscosity (BU)	Hot Paste Viscosity (BU)	Cold Paste Viscosity (BU)
DWR-162	Control	77.8	3.7	2.8	38	67.7	470	370	581
	0.25 g/100g a-DWR-162	80.0	3.3	2.5	43	67.3	712	670	816
	0.5 g/100g a-DWR-162	82.2	3.2	2.2	51	67.1	864	820	946
	0.25 g/100g a-HD-2189	78.1	3.6	1.9	54	66.4	536	433	640
	0.5 g/100g a-HD-2189	78.4	3.4	1.8	47	65.6	601	475	716
DWR-39	Control	75.5	3.9	2.5	56	67.3	530	454	628
	0.25 g/100g a-DWR-39	77.5	3.6	2.2	86	67.2	776	741	886
	0.5 g/100g a-DWR-39	80.5	3.4	2.1	73	66.4	842	793	926
	0.25 g/100g a-MACS-2496	75.8	7.8	3.9	33	66.2	552	474	678
	0.5 g/100g a-MACS-2496	76.2	7.7	3.5	44	65.7	679	589	797
HD-2189	Control	69.8	4.5	1.6	52	74.5	472	458	617
	0.25 g/100g a-HD-2189	70.1	4.4	1.4	55	73.9	523	485	646
	0.5 g/100g a-HD-2189	70.4	4.4	1.2	50	72.6	620	546	759
	0.25 g/100g a-DWR-162	71.9	4.0	1.0	20	71.0	786	728	825
	0.5 g/100g a-DWR-162	74.0	3.8	1.0	14	70.2	840	797	955
MACS-2496	Control	71.5	6.2	2.7	58	75.8	285	249	369
	0.25 g/100g a-MACS-2496	71.8	6.0	2.5	64	74.0	308	280	411
	0.5 g/100g a-MACS-2496	72.1	6.0	2.5	51	73.7	333	309	460
	0.25 g/100g a-DWR-39	73.5	5.6	2.6	49	73.1	428	404	478
	0.5 g/100g a-DWR-39	75.6	5.1	2.6	40	72.0	498	442	550

*a-arabinoxylan.

flours obtained from HD-2189 and MACS-2496 varieties. Dough stability decreased on addition of arabinoxylans for all the flours and decreased by 0.6 min in DWR-162 flour when 0.5 g/100g arabinoxylan was added. There were marginal changes in mixing tolerance index (MTI) of flours, obtained from all the wheat varieties.

3.3.2. Effect of Arabinoxylans from Good Chapati Making Quality (GCMQ) Whole Wheat Flours to Poor Chapati Making Quality (PCMQ) Whole Wheat Flours and *Vice-Versa*

Water absorption increased by 0.3% and 0.6% on addition of 0.25 and 0.5 g/100g arabinoxylans from HD-2189 flour in DWR-162 flour, respectively. Similarly, WA increased by 0.3% and 0.7% on addition of 0.25 and 0.5 g/100g arabinoxylans from MACS-2496 flour in DWR-39 flour, respectively.

However, WA increased by 2.1% and 4.2% on addition of 0.25 and 0.5 g/100g DWR-162 flour arabinoxylans, respectively to HD-2189 flour. Similarly WA increased by 2.0% and 4.1% on addition of 0.25 and 0.5 g/100g DWR-39 flour arabinoxylans, respectively to MACS-2496 flour. The results clearly indicated that arabinoxylans from GCMQ flour exhibited higher water absorption. DDT decreased by 0.1 and 0.2 min on adding 0.25 and 0.5 g/100g arabinoxylans, respectively from PCMQ flour to GCMQ flour while DDT decreased by 0.5 to 1.1 min when arabinoxylans from GCMQ flour were added to PCMQ flour. The decrease in dough stability was 1 min, when 0.5 g/100g of HD-2189 flour arabinoxylan was added to DWR-162 flour. Least decrease (0.1 min) in dough stability was observed when 0.5 g/100g of DWR-39 flour arabinoxylan was added to MACS-2496 flour. There were marginal changes in mixing tolerance index values, when arabinoxylans from GCMQ flour were added to PCMQ flour indicating greater stability of the dough during mixing.

Although the increase in WA was observed upon addition of arabinoxylans in all the cases, it was more with the addition of isolated arabinoxylans of GCMQ flour, which might be due to their high arabinose content. There was a positive effect observed in PCMQ flour on adding isolated arabinoxylans from GCMQ flour. Arabinoxylans imbibe and hold water with the crosslinking density of the gel network and thus increase farinograph water absorption [24,25]. Jelaca and Hlynka [24] reported that arabinoxylan additions bring about changes in dough stability. During dough mixing, arabinoxylans act during the agglomeration of gluten following the breakdown of gluten structures and this may be the reason in alterations in rheological properties of whole wheat flour [26].

3.4. Effect of Arabinoxylans on the Amylograph Characteristics of Whole Wheat Flour

3.4.1. Effect of Arabinoxylans on the Same Variety of Whole Wheat Flour

Isolated arabinoxylans were added at 0.25 and 0.5 g/100g in the same variety of whole wheat flour and amylograph characteristics of whole wheat flour was studied (**Table 2**). Pasting temperature (PT) decreased from 67.7˚C to 67.3˚C, 67.1˚C for DWR-162 flour and 67.3˚C to 67.2˚C, 66.4˚C for DWR-39 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from the same variety of wheat. PT was high (74.5˚C and 75.8˚C) and it decreased to 73.9˚C, 72.6˚C and 74.0˚C, 73.7˚C for HD-2189 flour and MACS-2496 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from the same variety of wheat. Higher reduction in PT was observed for PCMQ flours. Peak viscosity (PV) increased from 470 to 712, 864 BU and 530 to 776, 842 BU upon addition of 0.25, 0.5 g/100g arabinoxylans from same variety of wheat for DWR-162 flour and DWR-39 flour, respectively. PV increased from 472 to 523, 620 BU and 285 to 308, 333 BU upon addition of 0.25, 0.5 g/100g arabinoxylans from same variety of wheat for HD-2189 flour and MACS-2496 flour, respectively. The increase in PV was high (312-394 BU) for GCMQ flours and it was low (48 - 148 BU) for PCMQ flours upon addition of 0.5 g/100g arabinoxylans. Similarly the increase in cold paste viscosity (CPV) was high (298-365 BU) for GCMQ flours and it was low (91 - 142 BU) for PCMQ flours upon addition of 0.5 g/100g arabinoxylans.

3.4.2. Effect of Arabinoxylans from Good Chapati Making Quality (GCMQ) Whole Wheat Flours to Poor Chapati Making Quality (PCMQ) Whole Wheat Flours and *Vice-Versa*

Pasting temperature (PT) decreased from 67.7˚C to 66.4˚C, 65.6˚C for DWR-162 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from HD-2189 flour and 67.3˚C to 66.2˚C, 65.7˚C for DWR-39 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from MACS-2496 flour, respectively. PT decreased from 74.5˚C to 71.0˚C, 70.2˚C for HD-2189 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from DWR-162 flour and 75.8˚C to 73.1˚C, 72.0˚C for MACS-2496 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from DWR-39 flour, respectively. Higher reduction in PT was observed for PCMQ flours when arabinoxylans from GCMQ flours were added. Peak viscosity (PV) increased from 470 to 536, 601 BU for DWR-162 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from HD-2189 flour and 530 to 552, 679 BU for DWR-39 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from MACS-2496 flour, respectively. PV increased from 472 to 786, 840 BU for HD-2189 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from DWR-162 flour and 285 to 428, 498 BU for MACS-2496 flour upon addition of 0.25 and 0.5 g/100g arabinoxylans from DWR-39 flour, respectively. The increase in PV was high when arabinoxylans from GCMQ flours were added in PCMQ flours. Similarly the increase in CPV was high (213 - 368 BU) for PCMQ flours upon 0.5 g/100g addition of arabinoxylans from GCMQ flours and it was low (131 - 149 BU) for GCMQ flours upon addition of 0.5 g/100g arabinoxylans from PCMQ flours.

It was observed that when whole wheat flours were added with isolated arabinoxylans of GCMQ flours, which have high arabinose-xylose ratio, the cold paste viscosity was very high compared to the other variations (**Table 2**). Yin and Walker [27] reported that water soluble arabinoxylans on adding to wheat flour exhibited positive effect on rheological properties by increasing dough paste viscosity. Earlier studies indicate that, addition of high molecular weight arabinoxylans increase and low molecular weight arabinoxylans decrease dough development time [28], however, in the present study it was based on A/X ratio, higher the ratio better was the dough quality.

3.5. Effect of Arabinoxylans on the Chapati Making Quality of Whole Wheat Flour

3.5.1. Effect of Arabinoxylans on the Same Variety of Whole Wheat Flour

1) Objective evaluation of chapatis

Chapatis were prepared from whole wheat flour upon addition of 0.25 and 0.5 g/100g arabinoxylans. The puffed height of chapatis increased significantly ($p \leq 0.05$) on addition of isolated arabinoxylans of same variety to the whole wheat flours (**Table 3**). The puffed height of chapatis prepared from DWR-162, DWR-39, HD-2189 and MACS-2496 wheat varieties upon adding

Table 3. Chapati making quality of wheat flours added with isolated arabinoxylans.

Wheat Varieties	Variations	Puffed height (cms)	Shear force (N)
DWR-162	Control	$5.5^{a} \pm 0.2$	$5.8^{a} \pm 0.3$
	0.25 g/100g arabinoxylan	$6.2^{c} \pm 0.1$	$4.8^{c} \pm 0.2$
	0.5 g/100g arabinoxylan	$6.5^{d} \pm 0.2$	$3.9^{d} \pm 0.1$
	0.25 g/100g HD-2189 arabinoxylan	$5.8^{b} \pm 0.1$	$5.5^{b} \pm 0.1$
	0.5 g/100g HD-2189 arabinoxylan	$6.0^{bc} \pm 0.1$	$4.9^{c} \pm 0.1$
DWR-39	Control	$5.3^{a} \pm 0.2$	$5.6^{a} \pm 0.2$
	0.25 g/100g arabinoxylan	$6.1^{c} \pm 0.1$	$4.7^{c} \pm 0.1$
	0.5 g/100g arabinoxylan	$6.4^{d} \pm 0.1$	$3.7^{d} \pm 0.2$
	0.25 g/100g MACS-2496 arabinoxylan	$5.5^{b} \pm 0.1$	$5.4^{b} \pm 0.2$
	0.5 g/100g MACS-2496 arabinoxylan	$5.9^{c} \pm 0.1$	$4.6^{c} \pm 0.1$
HD-2189	Control	$4.8^{a} \pm 0.1$	$7.0^{a} \pm 0.2$
	0.25 g/100g arabinoxylan	$5.3^{b} \pm 0.1$	$6.9^{b} \pm 0.1$
	0.5 g/100g arabinoxylan	$5.6^{c} \pm 0.2$	$6.0^{c} \pm 0.1$
	0.25 g/100g DWR-162 arabinoxylan	$6.0^{d} \pm 0.1$	$4.4^{d} \pm 0.1$
	0.5 g/100g DWR-162 arabinoxylan	$6.3^{d} \pm 0.1$	$4.2^{e} \pm 0.1$
MACS-2496	Control	$4.6^{a} \pm 0.1$	$4.8^{a} \pm 0.2$
	0.25 g/100g arabinoxylan	$4.9^{b} \pm 0.3$	$4.6^{b} \pm 0.3$
	0.5 g/100g arabinoxylan	$5.1^{c} \pm 0.5$	$4.3^{c} \pm 0.1$
	0.25 g/100g DWR-39 arabinoxylan	$5.3^{d} \pm 0.3$	$3.9^{d} \pm 0.1$
	0.5 g/100g DWR-39 arabinoxylan	$5.6^{d} \pm 0.1$	$3.6^{e} \pm 0.1$

[*]Data reported are expressed as mean ± SD; Means followed by different letters in the same column box differ significantly [$p \leq 0.05$].

0.25 g/100g isolated arabinoxylans of same variety increased by 0.7, 0.8, 0.5 and 0.3 cm, respectively; upon adding 0.5g/100g isolated arabinoxylans of same variety increased by 1.0, 1.1, 0.8 and 0.5 cm, respectively. The shear force of chapatis prepared from DWR-162, DWR-39, HD-2189 and MACS-2496 wheat varieties upon adding 0.25 g/100g isolated arabinoxylans of same variety decreased by 1.0, 0.9, 0.1 and 0.2 N, respectively; upon adding 0.5 g/100g isolated arabinoxylans of same variety decreased by 1.9, 1.9, 1.0 and 0.5 N, respectively.

2) Subjective evaluation of chapatis

The different attributes of sensory characteristics as judged by ten panellists are presented in **Table 4**. There were no significant changes in appearance of chapatis prepared from whole wheat flours containing added arabinoxylans. Tearing strength of chapatis decreased upon addition of arabinoxylans indicating that the chapatis were soft, which was also evident from objective measurement of shear force. The scores for pliability, aroma and eating quality increased on addition of isolated arabinoxylans.

3.5.2. Effect of Arabinoxylans from Good Chapati Making Quality (GCMQ) Whole Wheat Flour to Poor Chapati Making Quality (PCMQ) Whole Wheat Flour and *Vice-Versa*

1) Objective evaluation of chapatis

The puffed height of chapatis prepared from DWR-162 flour and DWR-39 flour on addition of isolated arabinoxylans of HD-2189 flour and MACS-2496 flour increased by 0.3 - 0.5 cms and 0.2 - 0.6 cms, respectively. The puffed height of chapatis prepared from HD-2189 flour and MACS-2496 flour on addition of isolated arabinoxylans of DWR-162 flour and DWR-39 flour increased by 1.2 - 1.4 cms and 0.7 - 1.0 cms, respectively (**Table 3**). The increase in puffed height was more when treated with arabinoxylans of GCMQ flour than the arabinoxylans of PCMQ flour.

The shear force of chapatis prepared from DWR-162 flour and DWR-39 flour on addition of isolated arabinoxylans of HD-2189 flour and MACS-2496 flour decreased by 0.3 - 0.9 and 0.2 - 1.0 N, respectively. The

Table 4. Effect of arabinoxylans on sensory properties of chapattis.

Wheat Varieties	Arabinoxylans	Appearance (10)	Shear force (10)	Pliability (10)	Aroma (10)	Eating quality (20)	Overall Quality (60)
	Control	$8.6^{a} \pm 0.2$	$8.5^{c} \pm 0.3$	$8.4^{c} \pm 0.2$	$8.5^{a} \pm 0.2$	$18.4^{c} \pm 0.1$	$52.4^{c} \pm 0.9$
	0.25 g/100g arabinoxylan	$8.7^{a} \pm 0.3$	$9.0^{b} \pm 0.4$	$8.9^{b} \pm 0.3$	$8.6^{a} \pm 0.2$	$18.8^{b} \pm 0.9$	$54.0^{abc} \pm 1.0$
DWR-162	0.5 g/100g arabinoxylan	$8.7^{a} \pm 0.4$	$9.5^{a} \pm 0.3$	$9.4^{a} \pm 0.2$	$8.7^{a} \pm 0.2$	$19.0^{a} \pm 0.4$	$55.3^{a} \pm 0.7$
	0.25 g/100g HD-2189 arabinoxylan	$8.6^{a} \pm 0.3$	$8.7^{c} \pm 0.2$	$8.6^{c} \pm 0.2$	$8.6^{a} \pm 0.2$	$18.6^{b} \pm 0.5$	$53.1^{bc} \pm 1.1$
	0.5 g/100g HD-2189 arabinoxylan	$8.6^{a} \pm 0.1$	$8.9^{b} \pm 0.1$	$9.0^{b} \pm 0.2$	$8.6^{a} \pm 0.2$	$18.8^{b} \pm 0.2$	$53.9^{abc} \pm 0.4$
	Control	$8.7^{a} \pm 0.3$	$8.5^{d} \pm 0.2$	$8.4^{c} \pm 0.1$	$8.5^{c} \pm 0.2$	$18.2^{b} \pm 0.1$	$52.0^{d} \pm 0.4$
	0.25 g/100g arabinoxylan	$8.7^{a} \pm 0.2$	$9.2^{b} \pm 0.3$	$9.0^{a} \pm 0.1$	$8.7^{b} \pm 0.3$	$18.5^{a} \pm 0.2$	$54.1^{b} \pm 0.2$
DWR-39	0.5 g/100g arabinoxylan	$8.9^{a} \pm 0.3$	$9.5^{a} \pm 0.1$	$9.2^{a} \pm 0.1$	$8.9^{a} \pm 0.4$	$18.9^{a} \pm 0.2$	$55.4^{a} \pm 0.2$
	0.25 g/100g MACS-2496 arabinoxylan	$8.7^{a} \pm 0.3$	$8.8^{cd} \pm 0.1$	$8.5^{b} \pm 0.1$	$8.7^{b} \pm 0.6$	$18.3^{b} \pm 0.7$	$53.0^{c} \pm 0.5$
	0.5 g/100g MACS-2496 arabinoxylan	$8.7^{a} \pm 0.3$	$8.9^{c} \pm 0.1$	$8.8^{b} \pm 0.1$	$8.7^{b} \pm 0.1$	$18.4^{b} \pm 0.4$	$53.5^{bc} \pm 0.5$
	Control	$7.3^{a} \pm 0.3$	$7.7^{e} \pm 0.2$	$7.4^{d} \pm 0.1$	$6.2^{b} \pm 0.2$	$14.2^{c} \pm 0.2$	$42.8^{e} \pm 0.5$
	0.25 g/100g arabinoxylan	$7.4^{a} \pm 0.3$	$8.3^{d} \pm 0.2$	$7.9^{c} \pm 0.1$	$6.3^{b} \pm 0.2$	$14.4^{c} \pm 0.3$	$44.3^{d} \pm 0.6$
HD–2189	0.5 g/100g arabinoxylan	$7.4^{a} \pm 0.4$	$8.6^{c} \pm 0.2$	$8.2^{b} \pm 0.1$	$6.4^{b} \pm 0.1$	$14.8^{b} \pm 0.3$	$45.4^{c} \pm 0.2$
	0.25 g/100g DWR-162 arabinoxylan	$7.4^{a} \pm 0.2$	$8.9^{b} \pm 0.2$	$8.6^{a} \pm 0.1$	$6.6^{a} \pm 0.1$	$15.1^{a} \pm 0.4$	$46.6^{b} \pm 0.3$
	0.5 g/100g DWR-162 arabinoxylan	$7.4^{a} \pm 0.3$	$9.2^{a} \pm 0.2$	$8.9^{a} \pm 0.2$	$6.7^{a} \pm 0.1$	$15.3^{a} \pm 0.4$	$47.5^{a} \pm 0.2$
	Control	$7.3^{a} \pm 0.3$	$7.4^{e} \pm 0.3$	$7.2^{e} \pm 0.3$	$6.2^{a} \pm 0.1$	$14.2^{c} \pm 0.9$	$42.3^{c} \pm 1.1$
	0.25 g/100g arabinoxylan	$7.4^{a} \pm 0.2$	$8.5^{d} \pm 0.3$	$7.6^{d} \pm 0.4$	$6.2^{a} \pm 0.1$	$14.4^{c} \pm 0.9$	$44.1^{b} \pm 0.2$
MACS-2496	0.5 g/100g arabinoxylan	$7.4^{a} \pm 0.3$	$8.8^{c} \pm 0.1$	$7.9^{c} \pm 0.2$	$6.3^{a} \pm 0.1$	$14.9^{b} \pm 0.8$	$45.3^{bc} \pm 1.0$
	0.25 g/100g DWR-39 arabinoxylan	$7.4^{a} \pm 0.2$	$9.3^{b} \pm 0.1$	$8.2^{b} \pm 0.1$	$6.3^{a} \pm 0.2$	$15.3^{a} \pm 0.7$	$46.5^{bc} \pm 0.5$
	0.5 g/100g DWR-39 arabinoxylan	$7.4^{a} \pm 0.3$	$9.6^{a} \pm 0.2$	$8.4^{a} \pm 0.1$	$6.3^{a} \pm 0.1$	$15.5^{a} \pm 0.7$	$47.2^{a} \pm 0.7$

*Data reported are expressed as mean ± SD; Means followed by different letters in the same column box differ significantly ($p \leq 0.05$).

shear force of chapatis prepared from HD-2189 flour and MACS-2496 flour on addition of isolated arabinoxylans of DWR-162 flour and DWR-39 flour decreased by 2.6 - 2.8 and 0.9 - 1.2 N, respectively (**Table 3**). The decrease in shear force was more when treated with arabinoxylans of GCMQ flour than the arabinoxylans of PCMQ flour. Lower shear force denotes that the chapatis have softer texture hence easy to tear [2] [Haridas Rao, 1993]. Soft texture is a desirable property of chapati that makes it easy to chew.

2) Subjective evaluation of chapatis

Chapatis prepared from DWR-162 flour and DWR-39 flour on adding isolated arabinoxylans of HD-2189 flour and MACS-2496 flour showed increase in the scores for tearing strength, pliability, aroma and eating quality. However, there was no significant ($p \leq 0.05$) difference in appearance of chapatis and the increase in scores of the former was not as high as the scores of chapatis prepared from DWR-162 flour and DWR-39 flour treated with isolated arabinoxylans of the same variety.

There was no significant difference in appearance and aroma of chapatis prepared from HD-2189 flour and MACS-2496 flour on adding isolated arabinoxylans of DWR-162 flour and DWR-39 flour. Significant improvement in the tearing strength and pliability of chapatis was observed in chapatis prepared from HD-2189 flour and MACS-2496 flour on adding isolated arabinoxylans of DWR-162 flour and DWR-39 flour (**Table 4**). Eating quality is an attribute observed during chewing and biting of chapatis. Chapatis having moderate tearing strength and more pliability result in a product requiring lesser effort to chew the chapatis. Tougher chapatis require more effort for biting, chewing, tearing action and such a mouthfeel is not desirable. Sensory scores for eating quality of HD-2189 flour and MACS-2496 flour chapatis on adding isolated arabinoxylans of DWR-162 flour and DWR-39 flour increased significantly. Isolated arabinoxylans of DWR-162 and DWR-39 treated whole wheat flours had positive impact on chapatis. Possible explanation would be that since isolated arabinoxylans of DWR-

162 and DWR-39 varieties had high arabinose to xylose ratio which exerts their functional role by means of their molecular structure, gelling capacity and influence the water distribution and water availability and there by influencing the chapati quality.

Earlier studies carried out on bread indicated that textural properties of bread are attributed to the presence of arabinoxylans in wheat as water absorption are governed by both protein and arabinoxylan content and their interactions [29]. Chapati water absorption and damaged starch are critical factors in determining the quality of chapati [30]. It is also reported that arabinoxylans exerts their functional role by means of their molecular structure, gelling capacity and influence the water distribution and water availability and thereby influencing the loaf volume and in turn the bread quality [31]. In the present study, dough characteristics upon addition of arabinoxylans had improved which was evident by increase in water absorption and viscosity of the dough. The positive impact on dough rheology has brought about the positive impact in chapati quality which is evident from textural and sensory property.

4. Conclusion

Addition of isolated arabinoxylans to whole wheat flours has improved the overall quality of chapatis. However, the isolated arabinoxylans from good chapati making wheat varieties have resulted in soft textured chapatis with improvement in overall quality compared to that of isolated arabinoxylans of poor chapati making wheat varieties. These improvements are attributed to differences in their arabinose to xylose ratio. Thus, the studies showed that the quality of chapatis can be improved by the addition of arabinoxylans isolated from good chapati making wheat varieties.

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