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Food Chemistry 88 (2004) 453–460
Food Chemistry
www.elsevier.com/locate/foodchem

Functional characteristics of non-starch polysaccharides (NSP) obtained from native (n) and malted (m) finger millet (ragi, *Eleusine coracana*, indaf-15) ☆

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Received 5 September 2003; received in revised form 12 January 2004; accepted 12 January 2004

Abstract

Non-starch polysaccharides (NSP) were isolated from a recently released, fast germinating hybrid variety of finger millet and its malt (ragi, Indaf-15), in different yields and their functional characteristics, such as viscosity, oxidative gelation capacity, foam stabilization, and their effects on various dough properties, were studied. Viscosities of hemicellulose-B (hemi-B) fractions, obtained from native and malted ragi flours, was found to be greater (N – 3.04 and M – 1.98 at 1% concentration) than all other NSP fractions. A linear increase in viscosity of this fraction was noticed with respect to its concentration; however it decreased as the temperature increased from 30 to 80 °C and it was found to be maximum at pH 6.0. Hemi-B was found to stabilize protein foams against thermal disruption and showed a high water absorption (4.4 ml at 1% concentration) compared to cold water-soluble polysaccharides (CWSP) (3.0 ml at 1% concentration). Minor variations in dough characteristics, such as dough development time (DDT), dough stability (DS), tolerance index (TI), maximum extensibility (Em) and maximum resistance (Rm) were noticed upon the addition of hemi-B polysaccharides obtained from native and malted ragi and also CWSP (N). However, a significant decrease in the above parameters was noticed upon the addition of CWSP (M). Similar patterns were also noticed in starch pasting characteristics, such as gelatinization temperature (GT), peak viscosity (PV), cold paste viscosity (CPV), hot paste viscosity (HPV), breakdown viscosity (BV) upon the addition of CWSP (N) and hemi-B (N&M). However, a visible decrease in the above parameters was noticed upon the addition of CWSP (M). Oxidative gelation studies indicated minor variations in their flow properties before and after the addition of hydrogen peroxide and peroxidase. The results obtained from this present study indicated that ragi can be incorporated as a source of dietary fibre both in the native and malted forms, in the preparation of various health foods without altering the dough characteristics or the quality of the end-product.

Keywords: Non-starch polysaccharides; Finger millet; Dough properties; Oxidative gelation; Viscosity; Pentosans; Farinograph; Amylograph

1. Introduction

Finger millet, also known as "ragi" in India, is an indigenous minor millet rich in minerals, particularly calcium (0.34%) and dietary fibre (18%) compared to cereals such as rice, wheat and maize. Studies were carried out with respect to: (a) changes in yields, neutral sugar composition of NSP (Malleshi, Desikachar, & Tharanathan, 1986; Subba Rao & Muralikrishna, 2001), (b) free and bound phenolic acids (Subba Rao & Muralikrishna, 2002) and (c) carbohydrates and the degrading enzymes (Nirmala, Subba Rao, & Muralikrishna, 2000) and nutrients and anti-nutrients (Mbithi-Mwikya, Van Camp, Yiru, & Huyghebaert, 2000).

☆ Presented at 17th National Carbohydrate symposium, held at CFTRI, Mysore Nov 21st and 22nd 2002.

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doi:10.1016/j.foodchem.2004.01.059

Non-starch polysaccharides (NSP), major components of dietary fibre, are known to influence the quantity of the end-product, because of their high water absorption capacity and also their ability to form viscous solutions. They are also recognized for their health beneficial effects, such as anti-diabetic, anti-tumerogenic and anti-atherosclerogenic effects (Subba Rao & Muralikrishna, 2002). Among all the NSP, pentosans are known to influence dough rheological properties and also to protect protein foams against thermal disruption. Hence, it is essential to study their effects on the quality of the various end products.

Ragi is widely used in its native, as well as germinated, forms in the preparation of various food products, such as ragi dosa (a pancake), ragi ''muddae'' (porridge), biscuits and, also, infant and geriatric foods and beverages (Narayanaswamy et al., 1971). Of late, it is also incorporated in the preparation of various biscuit preparations. The aim of the present study is to study the influence of various NSP fractions of ragi on the dough properties.

2. Materials and methods

2.1. Materials

Finger millet (Ragi) was an authentic, recently released, hybrid variety of ragi (Indaf-15); seeds were procured from V.C. farm of the University of Agricultural Science, Bangalore, located at Mandya, Karnataka, India.

Maida (a refined wheat flour devoid of most of the NSP) was obtained from the local market and was sieved in order to remove solid particles.

The Brabender farinograph, Brabender Extensograph and Brabender Amylograph were from, Duisburg, Germany.

Dinitro salicylic acid (DNS) and peroxidase (E.C. 1.11.1.7. from horse radish, 200–300 U/mg soild. One unit will form 1.0 mg purpurogallin from pyrogallol in 20 s at pH 6.0 at 20 °C) were obtained from Sigma Chemical Company, St. Louis, USA. Hydrogen peroxide (50% w/w). BSA, acrylamide, bis-acrylamide, ammonium persulphate (APS) and *N*,*N*,*N*′,-tetramethyl- enediamine (TEMED) were obtained from Sisco Research Laboratories, Mumbai, India. All other chemicals and solvents used were of analytical grade.

2.2. Malting

Malting was carried out according to the method of Nirmala et al. (2000). Ragi seeds (100 g) were cleaned, and steeped for 24 h and allowed to germinate for 96 h under controlled conditions on a moist cloth at 25 °C in a B.O.D. incubator. Germinated seeds were taken at 24 h intervals and dried at 50° in a hot air oven for 12 h. The vegetative growth portions were removed by gentle brushing, manually. Devegetated seeds were weighed, powdered and used for the isolation of NSP, along with ungerminated ragi flour as control.

2.3. Isolation and determination of sugar composition of NSP

Various NSP (CWSP, HWSP, hemicellulose-A (hemi-A), hemicellulose-B (hemi-B)), and alkali-insoluble residue (AIR) were isolated and their sugar compositions were determined as reported earlier (Subba Rao & Muralikrishna, 2001) .

2.4. Relative viscosity

Relative viscosity of polysaccharides, with respect to water, was determined according to the method of Muralikrishna, Ramdas Bhat, and Tharanathan (1987). Polysaccharide fractions were dissolved in water and the viscosity was determined in an Ostwald viscometer, with respect to temperature (30–80 °C), concentration (0.1–1.0%) and pH (2–10).

2.5. Foam stabilization

Foam stabilization effect of hemi-B polysaccharides was determined by using the method developed by Susheelamma and Rao (1979). To the protein solution (BSA, 1% 2.5 ml), taken in a graduated stoppered test tube, was added an aqueous polysaccharide solution (0.5–2.5%, 2.5 ml), sodium carbonate (5%, 1 ml) and citric acid (5%, 0.3 ml) and the initial volume (V1) was noted after thorough mixing. The solution was then heated at 90 °C for 3 min, cooled and, after 15 min, the final volume (V2) was noted. The difference between the final and initial volumes (V2−V1) gave an indication of foam stability of that polysaccharide. Suitable controls were prepared by taking a water protein solution instead of polysaccharide solution.

2.6. Oxidative gelation

Oxidative gelation of polysaccharides was carried out according to Vinkx, Van Nieuwenhove, and Delcour, 1991. To an aqueous polysaccharide solution (1%, 20 ml) was added H_2O_2 (0.39 g/l, 0.1 ml), and peroxidase (1 Sigma Purpurogallin unit, 0.1 ml) and kept for incubation at 30 °C .Relative viscosity, with respect to water, of the resultant mixture was determined at regular intervals (5, 10, 15, 20 min), as mentioned above. Reagent and substrate controls were prepared by taking water instead of polysaccharide/reagents and the difference in viscosity

between test and controls was taken as the oxidative gelation capacity of the polysaccharide.

2.7. Farinograph studies

Water absorption and mixing properties of wheat dough were determined by Brabender Farinograph, using a 50 g bowl, as approved by AACC (2000, 54-10). 50 g of maida, on 14% moisture basis, were kept in the bowl with or without additive (CWSP, hemi-B at 0.25 and 0.5% concentrations) and, during mixing, water was added from the burette to give a dough consistency of 500 BU and the following parameters were determined from the resulting farinogram: (a) % absorption of water, (b) dough development time (DDT), (c) dough stability (DS) and (d) tolerance index (TI).

2.8. Extensograph studies

Extensograph studies were carried out as approved by AACC (2000, 54-21) by using dough with 500 BU consistency, prepared by mixing maida (14% moisture basis), water and NaCl (2%, 6 g) in a 300 g Farinograph bowl with and without additives (0.25% and 0.5% of both CWSP and hemi-B). The prepared dough was cut into 50 g portions and subjected to extensograph studies. Maximum extensibility (Em) and resistance to extension (Rm) were measured after a rest period of 45 min.

2.9. Amylograph studies

Amylograph studies were carried out by following the method of AACC (2000, 61-01). The maida flour was slurried in 460 ml of citrate phosphate buffer (prepared by dissolving 14.8 g of anhydrous disodium phosphate and 10.3 g of citric acid monohydrate in 1 l of water, and 46 ml of this was diluted to 460 ml before use) by using a glass rod with and without polysaccharide (0.25 and 0.5%, CWSP and hemi-B) additives. The slurry was then transferred to the amylograph bowl and heated at a rate of 1.5 °C/min until it reached 96 °C. The resultant paste was maintained at the same temperature for 20 min (hold time) and it then started cooling at the same rate until it reached 50 °C. From the resulting amylogram, the following parameters were noted: gelatinization temperature (GT), peak viscosity (PV), breakdown viscosity (BV), hot paste viscosity (HPV), set back viscosity (SBV).

2.10. Determination of amylase activity

The amylase associated with CWSP was assayed by the method of Bernfeld (1955).

For extraction of amylases from CWSP, CWSP (1 g) was dissolved in 50 ml of citrate phosphate buffer (pH 4.8, 0.05 M) and extracted at 4 °C for 2 h, centrifuged at 7000 rpm for 15 min and the resulting supernatant dialyzed, and taken for the amylase activity assay.

For assay, soluble starch (1%) was gelatinized in citrate phosphate buffer (pH 4.8, 0.05 M) and incubated with a suitable aliquot of the above extract at 45 °C for 30 min. The reaction was stopped by adding DNS (1 ml) and the liberated reducing sugar was estimated after developing the colour by keeping the tubes in a boiling water bath for 10 min. The enzyme activity was represented as the amount of reducing sugar liberated/gramme of CWSP/min under the above-mentioned conditions.

3. Results and discussion

3.1. Sugar composition of the polysaccharides

Sugar compositions of the cold water-soluble polysaccharides (CWSP) and hemi-B isolated from native and malted ragi (96 h) were determined (Table 1). Water-soluble polysaccharides consisted more of hexoses than pentoses and there is clear degradation of pentosans after 96 h of malting. Hemicellulose-B, in contrast, consisted more of pentoses than hexoses, as indicated by the pentose to hexose ratio. After 96 h of malting, the pentose content decreased markedly due to the induction of cell wall-degrading enzymes (Nirmala et al., 2000).

3.2. Viscosity

Earlier results from our laboratory indicated that the relative viscosity of CWSP was low compared to hemi-B obtained from both native malted samples (ηr of CWSP

Table 1
Sugar compositions of cold water-soluble polysaccharide and hemicellulose-B isolated from native and malted ragi (96 h)

Polysaccharide	Condition	Rha	Ara	Xyl	Man	Gal	Glc	A:X	P:H
CWSP	Control (native)	8.50	26.7	10.6	5.5	17.9	30.7	1:0.40	0.69:1
	96 h	8.30	16.7	12.9	4.8	20.0	37.3	1:0.76	0.48:1
Hemicellulose-B	Control (native)	0.70	49.5	25.7	3.10	5.60	15.40	1:0.52	3.1:1
	96 h	1.00	35.0	20.5	4.50	9.00	30.00	1:0.58	1.26:1

A:X–arabinose:xylose ratio; P:H–pentose:hexose ratio.

(N), 1.05, of CWSP (M), 1.25, of hemi-B (N), 3.04 and of hemi-B (M), 1.98) (Subba Rao & Muralikrishna, 2001). In the present study the highly viscous fraction (hemi-B) was taken for further studies. The high viscosity of hemi-B, compared to all other NSP could be due to its higher pentosan content than the rest of the NSP, (Andrawartha, Phillips, & Stone, 1979; Subba Rao & Muralikrishna, 2001). The viscosity evidently increased with increase in concentration (0.1–1.0%), and decreased with increase in temperature (30–80 °C) and was maximum at pH 6.0 (Fig. 1). The increase in viscosity due to the increase in concentration is the result of greater chain interaction, which is evident in polysaccharides, in particular cereal arabinoxylans. The highest viscosity, at near neutrality (pH 6.0), is perhaps due to the repulsive effects of the negatively charged carboxyl group that extends the chain and increases its water-binding capacity, typical of acidic polysaccharides, gums and mucilages. The decrease in viscosity with increase in temperature can be explained by the gradual loss of hydration and also an increase in the distance between polymer chains (Whistler & Be Miller, 1973). These results are in close agreement with those reported for 10% TCA extractable cowpea, blackgram and linseed polysaccharides (Muralikrishna et al., 1987). The viscosity of any polysaccharide solution is governed, not only by its over all conformation, but also by the specific arrangement of substituent residues along the backbone (Izydorczyk & Biliaderis, 1995).

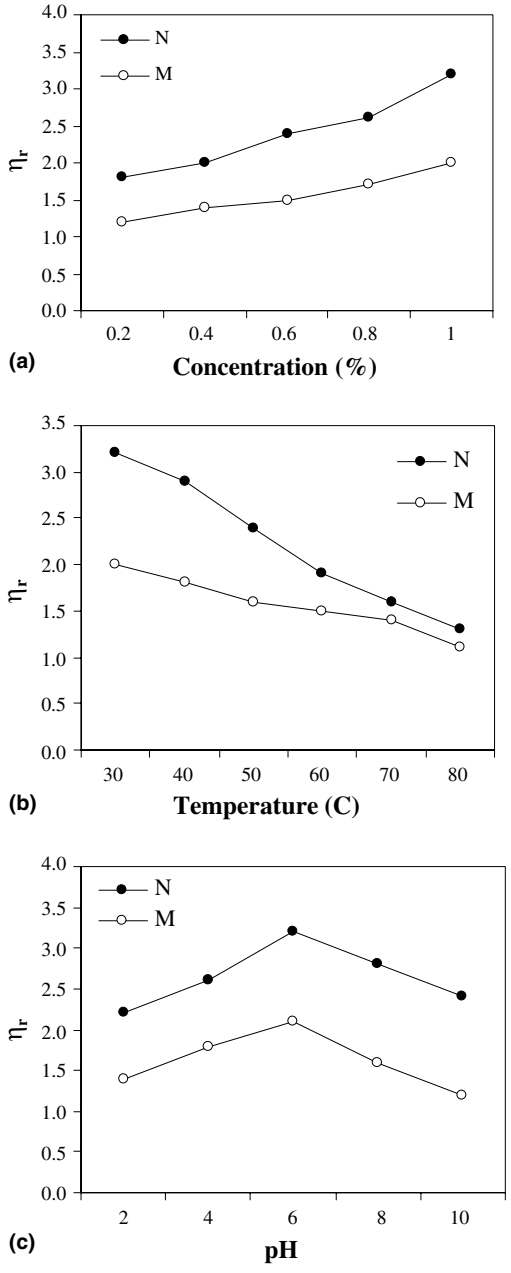

Fig. 1. Changes in relative viscosity (η_r) of hemi-B (average of 6 readings) obtained from native (N) and malted (M) ragi with respect to: (a) concentration; (b) temperature; (c) pH.

3.3. Oxidative gelation

Hydrogen peroxide/peroxidase-mediated cross-linking of water extractable polysaccharides, especially arabinoxylans, has been investigated for over 30 years and this cross-linking ability of polysaccharides was attributed to the associated ferulic acid residues (Schooneveld-Bergman, Dignum, Grabber, Beldman, & Voragen, 1999). In the present study, viscosity of CWSP and hemi-B polysaccharides did not change before or after the addition of hydrogen peroxide and peroxidase(data not shown). Results similar to those obtained in the present study were reported in wheat, wherein the relative viscosity of water-soluble polysaccharides remained the same at lower concentrations (until 0.4%); however, a slight increase was noticed in viscosities at higher concentrations (<0.4%). In contrast, the polysaccharides obtained from rye have shown a significant increase in their viscosity upon the addition of hydrogen peroxide and peroxidase (Vinkx et al., 1991). The authors explained this by the low molecular weight of wheat water-soluble polysaccharides compared to those obtained from rye. The results obtained in the present study can be explained by the ferulic acid content. Since the ferulic acid content of CWSP was very low (results not shown), it might not have gelled in the presence of the above reagent mixture. In the case of hemi-B, the associated feruloyl groups might have been lost during alkali extraction (10% alkali), as a result of its inability to form gels. Bound phenolic acids are known to be extractable from cell wall polymers by 1 N alkali (Subba Rao & Muralikrishna, 2002).

3.4. Foam stabilization

Stabilization of protein foams against thermal disruption by hemi-B polysaccharides obtained from native

and malted ragi is evident in Table 2. The results obtained in the present study indicated that the protein foam stabilization effect is greater with highly viscous guar and xanthan gums than with hemi-B polysaccharides obtained from native and malted ragi. Hemi-B polysaccharides obtained from native ragi had a greater stabilizing effect than malted ragi, at all the concentrations tested. This effect increased as the concentration increased. A visible decrease in the foam volume occurred, compared to the control, immediately after the addition of polysaccharide solution, which could be due to the high viscosity. Results similar to those obtained in the present study were also reported in wheat soluble pentosans (Izydorczyk & Biliaderis, 1992), cowpea, black gram and linseed mucilage polysaccharides (Muralikrishna et al., 1987). Polysaccharides are known to stabilize protein foams against thermal disruption, not only by virtue of their high viscosity, but also by their ability to interact with the proteins adsorbed to the foam cells (Sarker, Wilde, & Clark, 1998).

3.5. Farinography studies

3.5.1. Water absorption

The changes in water absorption of the base flour (maida, refined wheat flour) and dough characteristics, caused by the addition of ragi NSP fractions (CWSP and hemi-B at 0.25 and 0.5% levels), were assessed by using a Brabender farinograph (constant flour) method and the results are shown in Table 3. The water absorption values of hemi-B (4.4%) were found to be greater than CWSP (3.0%) in both N&M samples. The high water absorption values of hemi-B fractions can be correlated with their high pentosan content. Pentosans are known to have high water absorption capacity. Water-soluble arabinoxylans caused an increase in water absorption similar to that reported for wheat crude pentosans, wherein the water absorption values varied from 4.2% to 6.2% depending on the source of pentosan (Jelaca & Hlynka, 1971). However, these values are significantly lower than those reported for pentosans obtained from wheat endosperm (water-soluble pentosans 11 times and water-insoluble 10 times their weight) (Kulp, 1968).

3.5.2. Dough development time

A slight increase in the DDT was noticed upon the addition of CWSP (by 0.5 min for both N&M at 0.25% concentration) and hemi-B (N by 0.5 and 1.0 min, at 0.25 and 0.5% concentrations, respectively). However, there was no change in the DDT upon the addition of hemi-B (M, at both 0.25 and 0.5 concentrations) or CWSP (N&M of 0.5% concentration). A slight increase in DDT (by 1.0 min at 1% concentration) was reported upon the addition of water-soluble pentosans obtained from wheat flour (Biliaderis, Izydorczyk, & Rattan, 1995). However, no changes were reported in DDT upon the addition of water-insoluble pentosans (Kulp & Bechtel, 1963)and they concluded that this is due to similar water absorption values of the water-soluble and water-insoluble arabinoxylans. Similar observations were observed in the present study, wherein the water absorption values are the same for both native and malted hemi-B polysaccharides. The small increase in DDT upon addition of hemi-B (N) may be due to the high viscosity compared to the malted sample.

3.5.3. Dough stability

Dough stability was not changed upon addition of CWSP (N) at 0.25% or hemi-B (N, 0.25% and 5%). However, a slight increase, by 0.5 and 1 min, was noticed upon addition of CWSP (N, 0.5%) or hemi-B (N, 0.5%) concentrations. Kulp and Bechtel (1963) reported that the addition of water-insoluble arabinoxylans did not change the DS. A visible decrease in DS occurred upon addition of CWSP (M), and the decrease was greater at high concentrations of the additive. Jelaca and Hlynka (1971) reported minor variations in DS after incorporation of wheat crude pentosans. The visible decrease observed in DS, by the incorporation of CWSP

Table 2
Foam stabilization properties of hemicellulose-B from native and malted ragi

Additive	Concentration (%)	A[a] (ml)		B[a] (ml)		A–B (ml)	
		N	M	N	M	N	M
None	–	7.2	–	–	1.0	6.2	–
Guar gum	1.0	6.0	–	5.0	–	1.0	–
Gum xanthan	1.0	6.2	–	5.0	–	1.2	–
Hemi-B	0.5	7.2	7.2	2.0	1.5	5.2	5.7
	1.0	7.0	7.2	2.2	1.8	4.8	5.4
	1.5	6.8	7.0	3.0	2.2	3.8	4.8
	2.0	6.0	6.6	4.0	2.8	2.0	3.8
	2.5	5.6	6.2	4.6	3.0	1.0	3.2

A: initial volume of the foam; B: foam volume after heating at 95 °C for 3 min; N: native; M: malted (96 h). Studies were not carried out with CWSP because of its low viscosity.

[a] Averages of three independent experiments.

Table 3
Effects of polysaccharide additives (CWSP and hemi-B) from native and malted ragi, on farinograph dough characteristics

Additive	Sample	Concentration of the additive (%)	% Moisture absorption	DT (min)	DS (min)	TI (BU)
None			60.20 ± 0.2	4.5 ± 0.1	8.0 ± 0.1	40 ± 5
CWSP	N	0.25	61.00 ± 0.2	5.0 ± 0.1	8.0 ± 0.1	60 ± 5
		0.50	61.40 ± 0.2	5.0 ± 0.1	8.5 ± 0.1	40 ± 5
	M	0.25	61.00 ± 0.2	5.0 ± 0.1	6.5 ± 0.1	80 ± 10
		0.50	61.40 ± 0.2	4.5 ± 0.1	5.5 ± 0.1	100 ± 10
HEMI-B	N	0.25	61.20 ± 0.2	5.0 ± 0.1	8.0 ± 0.1	40 ± 5
		0.50	62.40 ± 0.2	5.5 ± 0.1	9.0 ± 0.2	40 ± 5
	M	0.25	61.20 ± 0.2	4.5 ± 0.1	8.0 ± 0.1	60 ± 5
		0.50	62.40 ± 0.2	4.5 ± 0.1	8.0 ± 0.1	60 ± 5

N: native; M: malted (96 h); CWSP: cold water-soluble polysaccharide; Hemi-B: hemicellulose-B, DDT: dough development time; DS: dough stability; TI: tolerance index. BU: Brabender units.

Table 4
Effect of polysaccharide additives (CWSP and hemi-B) obtained from native and malted ragi, on extensograph characteristics

Additive	Sample	Concentration of the additive (%)	Rm (BU)	Em (mm)	Em/Rm (mm/BU)
None			460 ± 10	115 ± 2	0.25
CWSP	N	0.25	400 ± 10	120 ± 3	0.30
		0.50	420 ± 10	115 ± 2	0.27
	M	0.25	340 ± 10	130 ± 4	0.38
		0.50	280 ± 10	150 ± 5	0.53
Hemi-B	N	0.25	380 ± 10	120 ± 3	0.32
		0.50	400 ± 10	110 ± 2	0.27
	M	0.25	400 ± 10	120 ± 3	0.30
		0.50	400 ± 10	120 ± 3	0.30

Rm: maximum resistance, Em: maximum extensibility.

(M), could be due to the associated amylase, which might have acted upon the starch component of the starch-gluten network, resulting in its weakening. A significant amylase activity (4.48 U/100 mg of CWSP) was noticed in the CWSP (M) fraction. Amylases are induced during malting of cereals and millets and can be extracted by using, not only buffers but also water and saline solution (Nirmala et al., 2000). The starch-gluten net work is one of the major factors determining the stability of the dough and added pentosans are known to enhance the loaf volume of the starch-gluten system (Delcour, Van hamel, & Hoseney, 1991).

3.5.4. Tolerance Index

Tolerance index values were not much effected after addition of CWSP (N) or hemi-B (N&M). However, a significant decrease was noticed after incorporation of CWSP (M) which could be explained by associated amylase activity.

3.6. Extensograph studies

The main objective of this experiment was to determine the effects of NSP additives on the extensibility properties (Em and Rm) of dough. These values (Em and Rm), which give the shape of the curve, are very important for determining the effect of dough improvers (Bloksman, 1971). The results indicated a slight decrease in the Rm values (460 BU to 380 at 0.25% and 400 at 0.5%) of hemi-B (N&M) and CWSP (N)-fortified doughs. The decrease in Rm values was much greater with CWSP (M), with a concomitant increase in Em values (115–130 mm at 0.25% and 150 mm at 0.5%, Table 4). This could be due to its associated amylase activity. Results similar to those reported here was also observed in the case of wheat, wherein the addition of water-insoluble pentosans resulted in a decrease in resistance (830–783 BU and 910–860 BU) (Kulp & Bechtel, 1963).

3.7. Amylograph studies

The results obtained by amylograph studies indicated a slight increase (1.5°) in GT upon addition of CWSP (N, 0.5%) and hemi-B (N&M at both concentrations, Figs. 2 and 3). This could be due to the water absorption capacity of these polysaccharides. Since gelatinization is a water-dependent process, a small decrease in the available water content upon addition of pentosan rich hemi-B polysaccharides might have resulted in the ob-

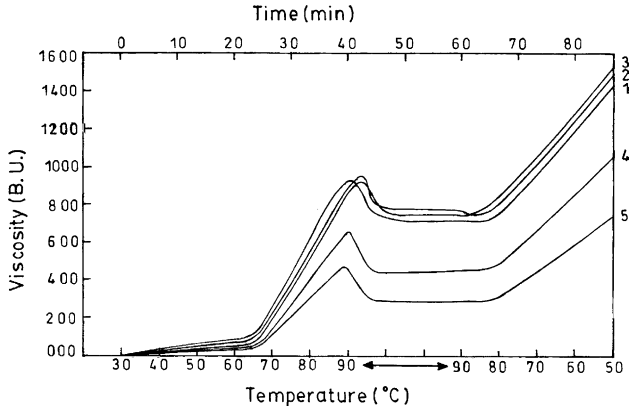

Fig. 2. Brabender visco-amylograms of CWSP (N&M); 1. Control, 2. CWSP (N 0.25%), 3. CWSP (N 0.5%), 4. CWSP (M 0.25%), 5. CWSP (M 0.5%).

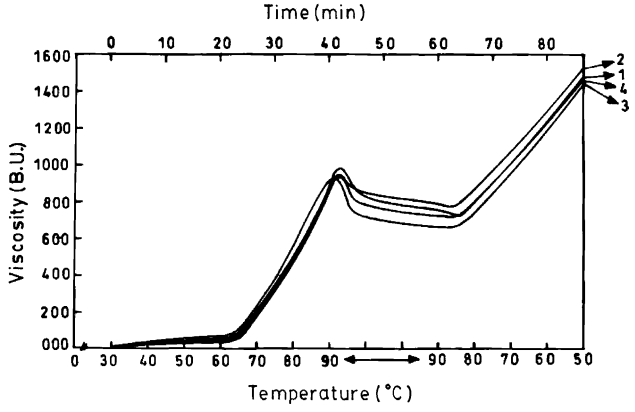

Fig. 3. Brabender visco-amylograms of hemi-B (N&M); 1. Hemi-B (N 0.25%), 2. Hemi-B (N 0.5%), 3. Hemi-B (M 0.25%), 4. Hemi-B (M 0.5%).

served increase in the G.T. Observations similar to those reported in the present study were also reported by Gudmundsson, Eliasson, Bengtsson, and Aman (1991), wherein the addition of water-soluble arabinoxylans, obtained from rye, to the starch solutions resulted in a slight increase in GT (0.4 °C at 1% concentration of the additive).

Other parameters, such as peak, cold and hot paste viscosities and breakdown viscosity, did not change much after addition of CWSP (N) or hem-B (N&M, Table 5). (Kulp & Bechtel, 1963) reported that the addition of wheat water-insoluble arabinoxylans did not change the PV or initial rise of the wheat starch pasting curve. However, a substantial decrease in the above parameters was noticed on addition of CWSP (M) and the effect was greater at higher concentrations of the additive. This could be due to the action of associated amylases on gelatinized starch, thereby resulting in the substantial decrease in a viscosity of the starch paste.

4. Conclusions

The results obtained in the present study indicated that the hemi-B fractions obtained from native (N) and malted (M) ragi flours, because of their high viscosity, showed greater foam stabilization than those of the CWSP fraction. The dough characteristics, such as dough development time (DDT), dough stability, extensibility and starch pasting behaviour, were not changed significantly, upon incorporation of CWSP (N) or hemi-B (N&M) fractions. The major changes noticed in all the functional characteristics, upon incorporation of CWSP (M) may be due to associated amylase. Finally, it can be concluded that, the incorporation of ragi NSP (components of dietary fibre) had no significant bearing on the functional properties of dough, except in acting as foam stabilizers. Malting resulted in the induction of amylases, which is a positive attribute in the preparation of sugar-rich food items, and caused various changes in dough properties.

Table 5
Effect of CWSP and hemi-B obtained from native and malted samples on starch pasting characteristics by Brabender Amylograph

Additive	Malting time (h)	Concentration (%)	GT (°C)	PV (BU)	CPV (BU)	BV (BU)	SV (BU)
None			61.5 ± 0.5	940 ± 10 (91.5)	1460 ± 20	260 ± 5	520 ± 10
CWSP	N	0.25	61.5 ± 0.5	960 ± 10 (91.5)	1500 ± 25	250 ± 5	540 ± 10
		0.50	63.0 ± 0.5	960 ± 10 (93.0)	1520 ± 25	220 ± 5	560 ± 10
	M	0.25	61.5 ± 0.5	640 ± 10 (90.0)	1060 ± 10	180 ± 5	420 ± 10
		0.50	61.5 ± 0.5	460 ± 10 (90.0)	760 ± 10	180 ± 5	300 ± 10
Hemi-B	N	0.25	63.0 ± 0.5	960 ± 10 (93.0)	1480 ± 20	280 ± 5	520 ± 10
		0.50	63.0 ± 0.5	980 ± 10 (93.0)	1520 ± 20	220 ± 5	540 ± 10
	M	0.25	63.0 ± 0.5	960 ± 10 (93.0)	1460 ± 20	280 ± 5	500 ± 10
		0.50	63.0 ± 0.5	960 ± 10 (93.0)	1480 ± 10	280 ± 5	520 ± 10

GT: gelatinization temperature; PV: peak viscosity; CPV: cold paste viscosity; BV: breakdown viscosity (PV–HPV); SV: set back viscosity (CPV–PV).

Acknowledgements

The authors thank Dr. V. Prakash, Director, CFTRI, for his keen interest and encouragement throughout this study. M.V.S.S.T.S.R, thanks the Council of Scientific and Industrial Research for the award of Junior and Senior Research Fellowships.

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