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Study on enrichment of whole wheat bread quality with the incorporation of tropical fruit by-product

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Abstract

In the present study Raw Mango Peel (RMP) powder was added to fortify whole wheat bread at three different levels (1%, 3% and 5 %) to increase its antioxidant properties than control (0% RMP powder) bread. This study also investigated the effects of RMP powder on the physical and sensory characteristics of bread along with the rheological effects on the dough. The content of polyphenols along with 2,2-diphenyl-1-picrylhydrazyl (DPPH) and Ferric reducing antioxidant powder (FRAP) value with a range of (21.51±0.45-68.54±2.15) % inhibition and (162.87±4.38-2232.31±47) µmol $FeSO_4$, $7H_2O$/ 100g fresh sample respectively increased linearly, showing greatest level at 5% RMP powder. Increase in the level of RMP powder, percentage weight loss, loaf height, loaf volume and whiteness index (WI) decreased but crumb moisture and loaf density increased with a significant change in brownness index (BI). Addition of peel also affected the rheological properties where addition leads to stiffer dough. Sensory evaluation through Quantitative Descriptive Analysis (QDA) showed that the incorporation of RMP powder increased the intensity of descriptors like hardness, rubbery texture, fruity aroma, after taste and decreased porosity and traditional bread aroma.

Introduction

Tropical countries possess a wide diversity of fruits and cereals with many possibilities of commercial exploitation; some of them are considered rare and exotic. Mango (*Mangifera indica* L.) a drupe fruit, belongs to family Anacardiaceae order Rutales. Grown abundantly in 85 different countries in the world comprising both the tropical and sub tropical region of the globe with an overall production of 33.45 MMT is regarded as one of the most important tropical fruits (FAOSTAT, 2007). Interestingly, the total tropical fruit consumed, mango takes up 50% of it labelling it as one of the most popular edible fruits in the world. India is the supreme producer of the fruit contributing to about 60% of world production by producing 13.5MMT of mango fruits (Bhattacharjee *et al*., 2011). As a seasonal fruit, raw mango is processed as some of the most popular food products such as puree, candy, amchoor (mango powder), nectar, leather, pickles, canned slices, marmalade, aam panna and chutney which are not only consumed nationwide but have also gained global market coverage and sales (Ravani and Joshi, 2013).

As some of the products are manufactured with the peel, many are formed by removal of the peel to obtain the succulent flesh. In this technique of processing, mango, which consists of about 15-20% of the peel (Tunchaiyaphum *et al.*, 2013) is generated as the major by product from various sources. This peel is discarded as a waste, therefore, proper treatment or sustainable utilisation of peel in any form can minimise the cost of waste treatment for industry and local administration as well as could be a measure of value addition and environment friendly waste management technique. Most studies on the exploitation of mango peels have been dealing with their use as a source of pectin (Kermani *et al*., 2015) which is considered as a high quality dietary fiber.

Mango peels were shown to be a good source of polyphenols, carotenoids, dietary fibre (pectin) and other bioactive compounds (Berardini *et al.*, 2005) as well as antiproliferative activities (Kim *et al*., 2010) which posses various beneficial effects on human health including protection against cardiovascular diseases, cancer and other degenerative diseases. Therefore, due to its massive health promoting affects mango peels are incorporated in muffins (Ramirez-Maganda *et al*., 2015), cookies (Bandyopadhyay *et al*., 2014) and macaroni (Ajila *et al*., 2010) as well as peels are fermented for wine (Varakumar *et al*., 2012) preparation.

In our study, oven dried RMP powder, has been

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incorporated at different levels (1%, 3% and 5%) in whole wheat bread to enhance its antioxidant properties. Thus, aim of our investigation was to study the improvement in antioxidant properties of whole wheat bread along with the physical, sensory and also rheological properties of the dough by addition of RMP powder at different levels.

Materials and Methods

Materials

Raw mangoes were procured from local market of Jadavpur, Kolkata, India. Whole wheat flour, granulated sugar, salt, refined oil (as shortening agent) was been purchased from the local grocery stores of Jadavpur, Kolkata. Compressed Baker's yeast (Saf Yeast Company Pvt. Ltd., Mumbai, India) was used as the leavening agent in bread preparation.

Chemicals

Chemicals, Glycerol monostearate (GMS) (Loba Chemie Pvt. Ltd., Mumbai, India) and Potassium bromate ($KBrO_3$) (Merck Specialities Pvt. Ltd., Mumbai, India) were also used in bread formulation. 2,4,6-tripyridyl-s-triazine (TPTZ) (Himedia Laboratories Pvt. Ltd., Mumbai, India), anhydrous ferric chloride (Rankem, New Delhi, India), ferrous sulphate heptahydrate, ethanol, Folin-Ciocalteau reagent, sodium carbonate, sodium acetate, acetic acid (Merck Specialities Pvt. Ltd., Mumbai, India), gallic acid (SD Fine-Chem Ltd., Mumbai, India) and DPPH (Sigma-Aldrich, St. Louis, MO, USA) were used in the investigation.

Preparation of the raw material

Raw mango peels were prepared by peeling freshly bought mangoes which were followed by washing with tap water to remove adhering dust and dirt particles. Then the peels were being blanched for enhancing its shelf life and improve the colour. The peel was spread in thin layers in trays and dried at 60 ± 2°C using a Tray dryer (Reliance Enterprise, Kolkata, India) for 18 h till the weight becomes constant. For ease in utilization the dried peel was powdered using a Grinder (GX7, Bajaj Electricals Ltd, India). The powdered peel for subsequent use was stored in air-tight packets in a refrigerator (-20ºC). The RMP powder was mixed at 1, 3 and 5% level with 100 g whole wheat flour for the preparation of desired composite flour.

Bread preparation

For the preparation of control bread, the activation of yeast was done by dissolving yeast (3 gm) in luke warm (at 37°C) water (20 ml) with previously dissolved sugar and kept for 15 min. In the meanwhile the dried material constituting whole-wheat flour 100 g, sugar 6 g, salt 1.5g and GMS 1.5 g with remaining components like $KBrO_3$ 1ppm were mixed in a bowl. Shortening (4 g), required amount of water (50 ml) and activated yeast were added and final mixing was done manually. The kneading was done for about 10 min for proper formation of gluten chain with appropriate mixing of ingredients in accordance to straight dough method. After this the first proofing at 30±2°C for 30 min was done by covering the bowl with wet cloth containing the rounded dough resulting in increase in volume. Further, at the juncture of second proofing the pre proofed dough was punched and kneaded slightly to remove the excess CO_2 from it. The worked up dough was transferred into greased moulds and kept for 1hr at 40±2°C with wet cloth cover. Finally, the bread was baked in rotary oven (CM HS108; Chanmag Bakery Machine Co. Ltd., Taipei, Taiwan) at 215±2°C for 20-24 min. The baked loaf was cooled at the ambient temperature for 1 h prior to packing in airtight bags. Similarly, the fortified bread samples were prepared by using composite flour (RMP powder at 1%, 3% and 5% level) in other ingredients (without $KBrO_3$).

Crumb moisture

The moisture content (dry basis) of bread crumb samples was measured by weight difference before and after drying of the samples (initial sample weight about 3 g) in a hot air oven (Reliance Enterprise, Kolkata, India) at 105°C (AACC, 2000).

Baking properties

Bread samples were weighed after cooling and loaf height was measured using a scale. The reading was taken from the top to the bottom of the loaf at three different sides (left, middle, and right). The average of the three readings was recorded. Volumes of the loaves were measured by the seed displacement method. From these, the specific volume (Steffolani *et al*., 2015), bread density and weight loss (Ho *et al*., 2013) of the loaf was calculated.

Texture

The textural profile analysis (TPA) of the crumb of bread samples was determined by the texture analyzer (TA.HD Plus Texture Analyzer, USA.). The analysis was done by a 35 mm diameter probe compressing the sliced bread (40 mm × 40 mm ×30 mm) at a cross-head speed of 0.1–2 mm/s. Hardness, cohesiveness and springiness of the crumb were measured based on the force–time curve (Bouane, 1978).

Loaf colour

The colour was measured using a Hunter Colour Measuring System, ColourFlex 45/0, D65, 10° observer (Hunter Associates Laboratory Inc., Reston, VA, USA). While to analyze the effect of colour change in the crumb, whiteness index is being measured (Ulziijargal *et al.*, 2013) as described in Eq. (1)

$$WI = 100 - ([100 - L]^2 + a^2 + b^2)^{1/2} \quad \ldots\ldots\ldots (1)$$

The brownness index (BI) was calculated (Shittu *et al.*, 2007) to measure colour change in the crust with the addition of RMP powder as described in: Eq. (2)

$$BI = \frac{[100(X-0.31)]}{0.17} \quad \ldots\ldots\ldots (2)$$

$$\text{Where, } X = \frac{(a + 1.75L)}{(5.645 \times L + a - 3.012b)}$$

Dough rheology

The dough samples without yeast with the same formulation of bread were used for studies. Dynamic oscillatory tests were performed in a controlled stress rheometer (Physica MCR 51 Anton Paar, Germany) with parallel plate of 49.986 mm and the measurements monitored with RheoPlus software package (version 2.65). All experiments were carried out at a constant temperature of 25°C. The flour dough was carefully placed between the plates. The upper plate was lowered to a fixed gap of 2.0 mm during loading. The excess of the dough sample outside the top plate edge was trimmed. A water-saturated filter paper to surround the measuring plates was used to minimise drying of the dough sample during measurement. All samples were allowed to rest for 5 min before measurements to allow dough relaxation. Frequency-sweep tests of the dough samples were performed at a constant strain of 1% and angular frequency ranging between 0.1 and 200 ω. Dynamic moduli G', G'' and tan δ (G''/G') were obtained as a function of frequency. G' is the dynamic elastic or storage modulus, related to the material response as a solid, while G'' is the viscous dynamic or loss modulus, related to the material response as a fluid. tan δ is related with the overall visco-elastic response: low values of this parameter indicate a more elastic nature (Das *et al*, 2013).

Extract preparation

Samples (1 g) in 80% aqueous ethanol was sonicated in a sonicator (Trans-o-sonic/D150-IM, Mumbai) at room temperature (approx. 25°C) for proper mixing of particle and centrifuged in cold (4ºC) at 8944×g for 15 min and the supernatant extracted by using a filter paper. The extracts were transferred into plastic tubes, and kept in the refrigerator until analysis.

Total phenolic content

The extract amounting 0.5 ml was dissolved in 1.8 ml of distilled water and 0.2 ml of the Folin-Ciocalteau reagent was added. After 5 min, 2 ml of 7% sodium carbonate was added and the contents mixed thoroughly by further addition of 0.8ml distilled water again. After incubation at room temperature for 90 min, colour developed and the absorbance was observed at 750 nm by UV-Vis spectrophotometer (U 2800; Hitachi, Tokyo, Japan) using gallic acid as a standard. The results were expressed as mg GAE/100 g fresh material (Singleton *et al*., 1997).

DPPH radical scavenging assay

The free radical scavenging capacity of sample extract was determined using the stable 2, 2-diphenyl-1-picrylhydrazyl radical (DPPH). The decrease in absorbance of the resulting solution was measured spectrophotometrically at 517 nm (Yu *et al.*, 2003). The percentage of inhibition or the percentage of discolouration was calculated as described in. Eq. (3)

$$\% \text{ Inhibition} = (Abs_{blank} - Abs_{sample}) \times 100 / Abs_{blank} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Ferric reducing antioxidant power (FRAP) assay

FRAP assay was based on the reduction of Fe^{3+}-TPTZ to a blue coloured Fe^{2+}-TPTZ. The FRAP reagent was freshly prepared by mixing acetate buffer (pH 3.6), TPTZ solution (10 mM TPTZ in 40 mM HCl) and 20 mM $FeCl_3$ solution in 10:1:1 v/v ratio. 100 µl of sample were taken and to it 3ml of the FRAP reagent added. The absorbance was taken at 0 and 30 min (after incubating at 37°C) at 593 nm. The antioxidant potential of the extracts was determined against a standard curve using $FeSO_4$, $7H_2O$ and expressed as µmol $FeSO_4$, $7H_2O$/100g fresh material (Benzie and Strain, 1996).

Sensory evaluation

Sensory analysis of raw mango peel fortified bread was done by quantitative descriptive method (QDA). Ten panellists (aged between 20 to 50 yrs), consisting students, research scholar and faculty members of the Dept. of Food Technology and Biochemical Engineering, Jadavpur University, Kolkata were selected for descriptive profiling test. The panel members were trained to recognise the changes in the sensory quality between the control and the RMP bread. Each training session was of 1 hr and total 3 sessions were conducted. The judges in the panel discussed about the parameter to be considered as sensory attributes of bread. Total 6 sensory attributes consisting porosity, traditional bread aroma, fruity aroma, crumb colour, after taste, hardness and rubbery texture were selected for consideration which invaded the parameters of appearance, aroma, colour, taste and oral texture. For evaluation, approximately 1cm thick slices including the crust and crumb, was presented to assessors. The assessors evaluated the samples on an unstructured 9 cm line scale labelled on the left by 'none' and on the right with the term 'strong'. Ratings were registered on an evaluation form. The samples were kept in a 3-digit coded glass covered with a glass lid. Samples were assessed in triplicates in four sets (Heenan *et al.*, 2008).

Statistical analysis

The experimental design was completely randomized, with three replicates. All data were expressed as mean values ± SD. All the experimental data were analyzed statistically for analysis of variance (ANOVA) with Microsoft Excel 2007. The scores for QDA was analysed by analysis of variance (two-way ANOVA as factors) applied to (panellist and sample) and their interaction to study the differences between the samples. The comparisons between the mean values were tested using Duncan's new multiple-range test at a level of $p \leq 0.05$.

Results and Discussion

Crumb moisture and baking properties

The effect of addition of RMP powder on crumb moisture and baking properties the bread samples are shown in Table 1. The moisture content increased linearly due to the addition of RMP highest at 5%. The fiber is water retaining, expandable, adsorptive hence the digestive enzyme fails to decompose it (Shyu *et al.*, 2013). By previous studies we can assume that the addition of a fibre containing substance can elevate the moisture content of a baked product (Lim *et al.*, 2011).

Significant variations were observed in various baking quality parameters of peel bread. RMP powder 5% had the lowest weight loss value (7.36%), which ranged from 15.64±0.60% to 9.04±0.32% decreasing significantly. This reduction may be attributed due to the addition of fibre which may not be easily consumed by the yeast during fermentation causing a barrier in fermentable sugar. In coordination with it the loaf height also decreases significantly, with a steep decrement where the lowest loaf height of 4.02 cm was indicated by 5% substitution. This indicates that peel substitution decrease height of the final baked product.

The specific volumes of the bread ranged from (2.69±0.05 to 2.10±0.02) cm^3/g. The highest level addition of peel resulted in the lowest specific volume. In terms of loaf density, bread containing RMP powder, were significantly ($p \leq 0.05$) denser than the control. Possible explanations for the high density of bread may include factors such as water holding capacity of peel containing both soluble and insoluble fibre (Dhillon and Kaur, 2013). Bread with high density was also low in specific volume with less visible air pockets due to the compact crumb structure.

Texture and loaf colour

The textural and colour parameters are shown in Table 2. The hardness of the bread increased linearly as the amount of addition of RMP powder increased showing the maximum value of at 5% substitution. This is in accordance with the addition of other non-wheat based gluten free products where addition of quinoa leafs increased the hardness of the bread crumb (Świeca *et al.*, 2014). The partial substitution of whole wheat bread by a non-porteinous fibre rich powder may lead to change in yeast activity along with stiffening of the air cells leading to a more firm crumb texture. Following the same trend a significant increase in cohesiveness and springiness of the bread fortified with RMP powder was observed in comparison to the bread without peel powder. A greater amount of sugar in mango peels causing the adhesion of the particle might forms a sticky network contributes to the increased cohesiveness of the substituted bread. This observation was also concluded when chestnut flour was added in bread (Dall'Asta *et al.,* 2013). However, some studies also show that the springiness increased at higher percentage of incorporation (Mildner-Szkudlarz *et al.*, 2010).

Colour is an important quality indicator for baked food products which indicates various factors including raw material, baking temperature and time etc. The whiteness index (WI) of the incorporated samples differed significantly from the control. Furthermore the incorporation of 3% and 5% of RMP powder significantly affected the crumb colour imparting a slight green colour due to the addition of raw peel. This attribute was rather attractive from

Table 1. Crumb moisture and baking properties of the bread samples substituted with RMP powder at different levels

Parameters	0% (control)	1%	3%	5%
Moisture (%)	31.63±0.72[a]	40.16±0.59[b]	43.47±0.35[c]	46.49±0.63[d]
Weight loss (%)	15.64±0.60[d]	12.01±0.22[c]	9.04±0.32[b]	7.36±0.22[a]
Loaf height (cm)	5.54±0.4[c]	5.03±0.62[c]	4.6±0.33[b]	4.0±0.2[a]
Specific volume (cm^3/gm)	2.69±0.05[d]	2.43±0.36[c]	2.23±0.15[b]	2.10±0.02[a]
Density (g/cm3)	0.37±0.02[a]	0.41±0.02[b]	0.44±0.01[c]	0.48±0.02[d]

Each value is expressed as mean ± SD (n = 3). Mean with different letters within a row is significantly different ($p \leq 0.05$).

Table 2. Textural and colour parameters of the bread samples substituted with RMP powder at different levels

Parameters	0% (control)	1%	3%	5%
Hardness (N)	2.6±0.11[a]	3.2±0.14[b]	3.7±0.16[c]	4.0±0.19[c]
Cohesiveness	0.26±0.01[a]	0.30±0.01[b]	0.60±0.03[c]	0.72±0.02[d]
Springiness	0.30±0.01[a]	0.36±0.01[b]	0.40±0.02[c]	0.55±0.02[d]
WI	57.57±1.18[d]	54.67±0.93[c]	52.47±1.3[b]	50.67±0.96[a]
BI	79.71±5.2[a]	87.25±3.6[a]	90.37±1.28[b]	121.47±17.12[c]

Each value is expressed as mean ± SD (n = 3). Mean with different letters within a row is significantly different ($p \leq 0.05$).WI (whiteness index), BI (brownness index)

consumer viewpoint and has also been indicated in anka enriched bread (Tseng *et al*., 2010). This result is also in compliance with the study (Wu and Shiau, 2013) of pineapple peel where the incorporation of peel also significantly lowered the WI due to addition, imparting its own colour.

The crust of the breads containing RMP powder changed from brown to greenish brown. Colour analysis of the crust indicated that samples with the addition of RMP powder had darker crust, this can be ascribed to the darkening effects of Maillard and caramelization browning due its high sugar content, as previously hypothesized (Shittu *et al*., 2008) which could be attributed by the higher brownness index (BI) also studied earlier by (Das *et al*., 2012). However, the increase in brownness was significant at ($p \geq 0.05$), even at higher substitution level as the green colour of peel was suppressed by the dominant brown colour.

Dough rheology

A correct description of the changes in dough behaviour is necessary to maintain handling and machinability in industrialized production. The results of the frequency sweep test carried out on dough samples with RMP powder substituted and on the control samples are shown in Table 3. In all dough samples the storage modulus (G') was higher than the loss modulus (G"), indicating that the dough had a solid, elastic-like behaviour. Dough made with 5% of RMP powder showed statistically significant differences in terms of damping factor (tan δ) and complex viscosity (η^*) compared to the other samples. Generally higher G' and lower tan δ indicate a more elastic and solid-like material.

The addition of RMP powder caused an increase of the G' twice as compared to G", indicates increased degree of elasticity of the dough. The decrease of tan δ implies that dough exhibits a different degree of

Table 3. Rheological parameters of the bread samples substituted with RMP powder at different levels

Parameters	0% (control)	1%	3%	5%
Storage Modulus (G') [Pa]	114540±3690^a	133397±8173^b	144949±2264^c	155686±5418^d
Loss Modulus (G") [Pa]	58525±761^a	61138±1619^b	67270±2857^c	74217±1418^d
Complex Viscosity (η *) [Pa.s]	4519.97±220^a	6182.727±108^b	7183.93±59^c	7549.96±377^d
Damping factor (tan δ)	0.507±0.02^c	0.479±0.01^b	0.463±0.02^a	0.455±0.01^a

Each value is expressed as mean ± SD (n = 3). Mean with different letters within a row is significantly different (p≤0.05).

Table 4. Total phenols and scavenging properties of the bread samples substituted with RMP powder at different levels

Parameters	0% (control)	1%	3%	5%
TPC (mg GAE/100gm)	227.66±7.5^a	443±11.0^b	510±12.5^c	794±8.32^d
FRAP (μM $FeSO_{4,}7H_2O$/ 100g)	162.87±4.38^a	476.13±11.08^b	1360.75±39.55^c	2232.31±47^d
DPPH (% inhibition)	21.51±0.45^a	33.61±0.78^b	61.19±1.90^c	68.54±2.15^d

Each value is expressed as mean ± SD (n = 3). Mean with different letters within a row is significantly different (p≤0.05).

cross-linking and that structural changes took place with changing RMP powder level. It is known that an increase in the cross-linking of a polymer system causes the G' to increase and the loss tangent to decrease (Watersa *et al,* 2011). Peel's addition, at the microstructural level, gives rise to a network with a higher density of cross-links. The increase in η^* indicated increased resistance to deformation. This is likely due to interactions between the fibre structure and the wheat proteins.

Antioxidant activity

Total phenolic content is an important parameter to study as it determines the polyphenolic content of the sample which is interrelated with the antioxidant activity of the sample. As shown in Table 4, the amount of phenolics increased proportionately to the increase of RMP powder level in the fortified breads. This, significant increase is in accordance with many tropical fruit (Moo-Huchin, 2015).

Table 4 shows the scavenging properties including DPPH and FRAP of the bread samples. It was noted that the values of DPPH and FRAP increased significantly indicating the scavenging properties of the fortified products. The values of FRAP (μM $FeSO_4$,$7H_2O$/ 100g) increased compared to the bread with no RMP powder, giving the highest value of 2232.31±47 μM $FeSO_4$,$7H_2O$ / 100g at 5% fortification. Whereas, the linear increment was also termed in DPPH (% inhibition) showing about three times leap from 0% to 5% RMP powder resulting a range of 21.51% to 68.54% inhibition.

The increase in total phenolic content and free radical scavenging activity may be attributed due to the presence of a rich variety of bioactive components such as polyphenols, dietry fibre and vitamin C etc (Ajila *et al*., 2007) in mango peels. The incorporation of mango peel powder in biscuit (Ajila *et al*., 2008) and macaroni (Ajila *et al*., 2010) have also shown

Table 5. Sensorial attributes and scores of the bread samples substituted with RMP powder at different levels

Sensory Descriptors	Samples 0% (control)	1%	3%	5%	Std dev
Porosity	7.59[d]	7.33[c]	7.11[b]	6.65[a]	0.40
Traditional bread aroma	8.43[d]	8.02[c]	7.69[b]	7.07[a]	0.57
Fruity aroma	2.17[a]	3.93[b]	4.63[c]	5.24[d]	1.33
After taste	2.59[a]	2.99[b]	4.03[c]	5.17[d]	1.15
Crumb Colour	6.71[a]	7.14[b]	7.48[c]	8.01[d]	0.55
Hardness	4.27[a]	5.03[b]	5.47[c]	6.46[d]	0.91
Rubbery	5.68[a]	6.15[b]	6.78[c]	7.07[d]	0.62

Mean with different letters within a column is significantly different ($p \leq 0.05$).

increased phenolic and scavenging property with increased in amount of addition of peel.

Sensory evaluation

The sensory attributes, with their assessment scores by the evaluators for each sample are shown in Table 5. All the samples were statistically different ($p \leq 0.05$) on the mentioned sensory attributes of the RMP fortified breads.

Porosity which represents the appearance of bread decreased significantly as the amount of fortification increased. The lower scores for incorporated sample compared to the control was may be due to the compact air cells in crumb caused by fibre addition. While observing the aroma descriptors, an inverse relationship between traditional bread aroma and fruity aroma was seen. As the amount of addition of level of peel increased the aromatic compounds masked the traditional yeasty aroma. However, the overall low scores of after taste which may include attribute of bitterness was low. As the amount of peel incorporation increased simultaneously the level of sugar causing a darker colour due to Millard reaction also increases leading to more intense crumb colour showing highest value at 5% RMP substitution. Considering the oral texture parameters both hardness and rubbery texture incremented significantly on addition of peel powder in bread. The values of both the descriptors for RMP bread were significantly larger when compared to bread with no level of peel also studied earlier, highest value at 5% RMP (Shin *et al*., 2013).

Conclusion

Addition of RMP powder at different percentage (from 0% to 5%) changes dough viscoelasticity, physical, antioxidant and sensory properties of bread. The dough with the highest amount of RMP powder (5%) showed the highest value of viscoelasticity evaluated by fundamental rheological measurements. This sample showed, after the lowest WI values regarding the crumb colour and the highest BI value for crust colour along with slight decrement in baking properties with greater retention of moisture. Incorporation of RMP powder in formulation markedly increased the total phenolics content and the radical scavenging activity of bread extracts. However, RMP incorporation at highest level increased the hardness, rubbery texture with significant decrease in crumb porosity and traditional bread aroma. Thus, optimum level of addition of RMP is an important factor to be considered. This leads to a conclusion that RMP powder at 3% can be added in bread to increase the antioxidant activity of whole wheat bread without much affecting the sensory attributes

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