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# Effect of Citrus Orange (*Citrus sinensis*) By-product Dietary Fiber Preparations on the Quality Characteristics of Frozen Dough Bread

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## ABSTRACT

High demand for fresh and healthy breads has necessitated the use of frozen dough to shorten the time and process for making fresh bread. The aim of this study was to study the effect of citrus fiber on breads produced from frozen dough. Citrus orange (*Citrus sinensis*) by-product Dietary Fiber (DF) was incorporated at different amounts (1-5%) into wheat flour and the dough properties evaluated using Farinograph. The dough obtained were frozen at -18°C for 1 month before being baked. Addition of fiber formulations to wheat flour showed increase in water absorption during dough mixing. Dough stability, development time and breakdown time showed a decreased trend with increase in fiber amounts. There was no significant difference in specific volume between control bread and 1% formulation while the rest showed a significant decrease in specific volume. All breads showed a significant increase in firmness from the control bread with a linear trend. All formulations showed marked increase in the dietary fiber content. Upon evaluation sonsorially by the panelist, control bread was the most acceptable bread followed by 1 and 2% formulations. However, there was no significant difference between the values, while the rest of the breads showed a significant difference with 5% being the least accepted. Low citrus by-product formulations had higher scores for flavor acceptability especially 2% formulation than the control. This study has shown that there is a great potential for production of fiber rich breads from frozen dough with a highly acceptable citrus flavor from citrus by-products.

**Key words:** Frozen dough, citrus by-product, dietary fiber, hypercholesterolemia, antioxidant

## INTRODUCTION

Citrus fruit is one of the most abundant fruit and it's juice is commercially produce worldwide with vast amount of waste (rind) which could be a potential source of functional dietary fiber for food applications. The use of whole fruit in citrus processing can reduce resource wastage, costs and provide a correct solution for the pollution problem associated with the process.

Dietary Fiber (DF) refers to the edible portion of plants or analogous carbohydrates that are resistant to digestion and adsorption in the human small intestine, with complete or partial fermentation in the large intestine (Sangnark and Noomhorm, 2004). Consumption of dietary fiber plays an important role in the prevention of illnesses such as constipation, reduction in the risk of colorectal cancer (Sabanis *et al.*, 2009) and hypercholesterolemia (Rupasinghe *et al.*, 2008), inhibition of cyclooxygenase and lipooxygenase which are related to prevention of thrombosis, atherosclerosis and carcinogenesis (Larrauri *et al*., 1996). The presence of bioactive compounds like flavonoids, with their antioxidant properties (Lario *et al*., 2004) may make citrus DF more beneficial than fibers from other sources.

Besides nutritional properties, dietary fibers are also important for their technological properties (Lario *et al*., 2004) such as prevention of syneresis and modification of viscosity and texture of formulated foods (Grigelmo-Migeul and Martin-Belloso, 1998). In food products such as breads, fibers from cereals are widely used, however, citrus fiber could be a good alternative (Chau and Huang, 2003) since fruits possesses higher total and soluble fiber contents, good water and oil holding capacities and ability to better support growth of beneficial microbial flora in (Vergara-Valencia *et al*., 2007).

Dietary fibers from fruit materials should be prepared in such ways that minimizes the loss of bioactive compound in order for their health effects to be realized (Figuerola *et al*., 2005). Drying is one of the processes involved during production of fibers and it can affect both the bioactive compounds and functional properties of fibers. Larrauri (1999) reported that higher drying rate (110°C, 8 kg $m^{-2}$) reduced the water holding capacity of the fiber produced. Thus careful choice for the type of dryer as well as the load per tray, drying temperature is very important when preparing fibers using commercial dryers. There is need to find new sources of DF that will confer the same or better benefits to both health and food systems like fibers from grains and seeds (Sanchez-Zapata *et al*., 2009). Therefore, citrus juice processing by-product provides such opportunity.

The aim of this study was to produce DF powder from citrus fruit processing by-product and to evaluate the influence of different fiber particle sizes on their physicochemical and functional properties. Furthermore, to evaluate the dough mixing properties after incorporation into wheat flour and assess the quality of the bread produced upon frozen storage of dough for one month.

## MATERIALS AND METHODS

**Preparation of fiber powder:** Orange by-products (albedo and oliferous vesicles) without peels from juice extraction were used as raw material source for production of orange dietary fiber powder. Orange by-product fiber was prepared according to method described by Larrauri (1999) and dried until it reached the final moisture content of less than 9 g/100 g wet weight or 9.9 g/100 g dry weight. The dried orange byproduct material was then ground to particle sizes <0.177->0.250 mm. The obtained fiber was then vacuum packed in an aluminum packet until further use.

### Fiber powder quality analysis

**Dietary fiber content:** The Dietary Fiber (DF) content was determined by the enzymatic-gravimetric method of Prosky *et al*. (1988) with slight modification. Sample (1 g) was placed in Erlenmeyer flask and weighed, 50 mL of phosphate buffer (0.08 M, pH 6) added and the pH adjusted to 6 with 0.325 N HCl or 0.275 N NaOH solutions. Erlenmeyer flask was then placed in a water bath at 100°C for 10 min. Then, 0.1 mL α-amylase (Sigma A-3306) added to each of them and the flasks left to incubate at the same temperature for 15 min under constant agitation. The flasks were then cooled rapidly and pH of samples adjusted to 7.5. After that, samples were placed in a water bath at 60°C for 10 min, 0.1 mL protease solution added to each of them (Sigma P-3910, 50 mg in 1 mL phosphate buffer) and mixtures left to incubate at the same temperature for 30 min. The flasks were cooled and pH adjusted again to 4 and then returned to the water bath at 60°C until samples reached this temperature. After adding 0.3 mL amyloglucosidase (Sigma A-9913), the samples were kept in the incubator for another 30 min under constant agitation. Insoluble Dietary Fiber (IDF) fraction was recovered by filtration on a sintered glass crucible, washed with distilled water, then dried overnight at 105°C and weighed. Soluble Dietary Fiber (SDF) fraction was obtained after precipitation of the obtained slurry with 95% ethanol (preheated to 60°C) at a ratio of (1:4 v/v). Precipitation was allowed to form at room temperature for 60 min, followed by filtration. The obtained residue was washed with 78% ethanol, 95% ethanol and acetone, then dried at 105°C overnight and weighed. Total Dietary Fiber (TDF) was calculated as the sum of SDF and IDF after correction for ash and undigested protein. DF was expressed as g/100 g dry samples.

**Proximate composition:** Moisture content was determined according to gravimetric heating method (130±2°C for 2 h). Total fat was determined according to method 922.06 of AOAC (1997). Ash was determined according to method 923.03 of AOAC (2000). Total Protein content was determined by the Kjeldahl method AOAC (2000) using the conversion factor of 6.25.

**pH:** The pH was determined by use of a pH meter (Mettler Toledo MP 220, Switzerland). It was carried out by direct measurement on a dry fiber/distilled water suspension at a ratio of 1:10 (w/v).

**Color:** Color determinations was made for both citrus by-product fiber and breads by determining the cieLab coordinates (L*, a*, b*) using MiniScan MS/Y-2500 (HunterLab, Inc, Reston USA), with illuminant D65 source

**Functional properties:**

**Water holding capacity:** Water Holding Capacity (WHC) was determined according to the method described by Robertson and Eastwood (1981) with a slight modification. Sample (100 mg) was added to 10 mL of distilled water in a 50 mL centrifuge tube and stirred overnight at 4°C. Then, the mixture was centrifuged at 14,000×g for 20 min and supernatant carefully removed. WHC was expressed as grams of water per gram of sample.

**Swelling capacity:** Water Swelling Capacity (WSC) refers to the ratio of the volume occupied when the sample is immersed in excess of water after equilibration to the actual weight. Accurately weighed dry sample (0.2 g) was placed in a 50 mL centrifuge tube and 10 mL of water added. Fiber sample was then allowed to hydrate for 18 h at 25°C at constant temperature and the final volume attained by the fiber powder mixture measured (Robertson *et al.*, 2000).

**Oil holding capacity:** Oil Holding Capacity (OHC) was measured according to method of Lin *et al.* (1974) by adding 15 mL of corn oil into 100 mg of sample in a 50 mL centrifuge tube. The obtained mixture was stirred and then centrifuged at 1600×g for 25 min. OHC was expressed as grams of oil per gram of sample.

**Farinograph:** Mixing properties of composite flour were carried out using a Farinograph equipped with a 300 g stainless bowl (Brabender Instruments Inc. Germany) in accordance with AACC method 54-21.02 (Miyazaki *et al.*, 2008) Water absorption (14% mb), dough stability, development time, arrival time and dough breakdown time were determined. The result was shown as a mean of triplicate determinations.

**Bread making:** Bread was baked using frozen dough according to the method described by Miyazaki *et al.* (2008) with slight modification. Seven grams of compressed baker's yeast for frozen-dough type was dissolved with an optimum amount of water determined by the Farinograph at 500 BU. Substituted wheat flour (500.0 g), sugar (90.0 g), egg (60.0 g), fat (40.0 g) and dissolved yeast were mixed in a Ladies mixer for 3 min slowly, followed by 2 min of fast mixing and later for 2 min upon addition of fat. The Kneaded dough was sheeted and put in a polythene bag, sealed and frozen at -18°C and stored in the freezer at the same temperature for 1 month. On the baking day, the frozen dough was thawed at 34°C for 60 min using a temperature and humidity regulated chamber. The dough was then rounded and fermented at 30°C and 85% RH for 30 min. The fermented dough was then divided into 130 g pieces, rounded by hand molding and proofed at 38°C and 85% RH for 30 min, followed by baking at 200°C for 20 min. The baked buns were allowed to cool for one hour at room temperature, then immediately weighed and the volume measured by rapeseed displacement method (AACC International, 2010) and specific volume calculated.

**Rheological property of the bread:** Bread crumb firmness was measured by rheometer (TA-XT2i, Stable Microsystems, Surrey, UK). The bun was sliced into a 30 mm thickness. The bread crumbs were compressed using P/25 aluminum probe at 5 mm $sec^{-1}$ of compression speed. The results are presented as an average of three measurements of different slices.

**Sensory evaluation of bread:** Sensory characteristics of bread were evaluated by a panel of 20 members of a group of food science students, ranging in age from 24-35 years according to method described by Sangnark and Noomhorm (2004) with a slight modification. The breads were evaluated for acceptability of color and appearance, flavor, texture and overall acceptability by hedonic 9-point scale where 9 represented extremely liked and 1 extremely disliked. Immediately before sensory testing, the buns were sliced into 30 mm thick slices. The end slices were discarded and a 4×4 $cm^2$ pieces were prepared and immediately placed in a plastic box. Each box was given a code number before testing.

**Statistical analysis:** Analytical determinations were performed in triplicate. Values of different parameters were expressed as the Mean±standard deviation. To assess for the differences in the means of different parameters, a Duncan's multiple range test at 95% confidence level was applied using the Statistical Package for the Social Sciences "SPSS" (version 19, IBM USA).

## RESULTS AND DISCUSSION

**Chemical composition:** The chemical composition analysis result of citrus by-product powder is shown in Table 1. The average moisture content was 9.25%, this was similar to those reported by Vergara-Valencia *et al.* (2007) for tangerine fiber and commercial dry products like wheat germ, oat cookies and bran flakes. The protein content was 0.43%, this value was lower than those reported for; citrus peels (3.1-8.3%) (Figuerola *et al.*, 2005), citrus by-products (6.55-12.87%) (Marin *et al.*, 2007) and tomato peel fiber (13.3%) (Navarro-Gonzalez *et al.*, 2011). This low value could be due the absence of peels in the by-product.

Table 1: Chemical composition of citrus by-product dietary fiber powder

| Coustituents | Orange by-product powder |
|---|---|
| Moisture (%) | 9.25±0.10 |
| Protein (%) | 0.43±0.08 |
| Ash (%) | 3.43±0.04 |
| Fat (%) | 6.57±0.52 |
| pH | 3.90±0.02 |
| Color L* value | 77.39±0.36 |
| Color a* value | 3.14±0.16 |
| Color b* value | 19.46±0.07 |
| Total phenolic content (GAE mg $g^{-1}$) | 48.89±0.20 |
| Iusoluble dietary fiber (g/100 g DW) | 53.07±1.23 |
| Soluble dietary fiber (g/100 g DW) | 17.97±1.40 |
| Total dietary fiber (g/100 g DW) | 71.04±1.92 |

Means±standard deviation of 3 replicates; L*: Lightness, a*: Redness, b*: Yellowness, GAE: Gallic acid equivalent, DW: Dry weight

Ash content was 3.43%, fat 6.57% and pH of 3.9. These values were similar to those reported for by-products from tomatoes and citrus by Figuerola *et al.* (2005), Marin *et al.* (2007) and Navarro-Gonzalez *et al.* (2011). The fairly high amount of total fat could be attributed to the seeds in the citrus by-product. The color of the by-product powder had values of 77.39, 3.14 and 19.46 for L*, a* and b* cieLab coordinates respectively. These values were slightly higher than those reported by Grigelmo-Migeul and Martin-Belloso (1998) for orange dietary fiber concentrate. This may be due to differences in preparation methods and composition of the materials. A bright white color for flour is generally desirable (Shelton, 2004).

The total phenolic content value was 48.89 gallic acid equivalent (GAE) mg $g^{-1}$, showing a lower content than those reported for fibers from tomato peel (158.1 mg GAE/100 g). However, it was slightly higher than those reported for orange (*C. aurantium* cv. *Canoneta*) (0.51 mg GAE/100 g), lime (*C. aurantifolia* cv. *Persa*) (0.35 mg GAE/100 g) (Navarro-Gonzalez *et al.*, 2011) and mango 16.14 mg $g^{-1}$ (Vergara-Valencia *et al.*, 2007).

The total, soluble and insoluble dietary fiber contents were 71.04, 17.97 and 53.07 g/100 g DW Table 1. The value for insoluble fiber was in agreement with those reported for orange peel fiber (54.0 g/100 g) by Figuerola *et al.* (2005) but higher for both soluble fiber (10.28 g/100 g) and total dietary fiber (64.3 g/100 g). It was also higher than the value for insoluble dietary fiber reported for Granny Smith and Royal Gala apples (56.5 and 63.9 g/100 g) in that report.

## Physical properties of citrus by-product powder

**Water holding capacity:** The citrus by-product fiber showed significant variation ($p<0.05$) in WHC with larger particles holding more water than the fine particles as shown in Table 2. Particle sizes >0.250 mm had a WHC of 6.44 g water/g dry sample, while particle size 0.177 mm had value of 5.97 g water/g dry sample and those <0.177 mm was 5.08 g water/g dry sample. The observed WHC in this study was similar to those reported by Lario *et al.* (2004) (6 g water/g fiber) and Grigelmo-Migeul and Martin-Belloso (1998), however, they were lower than those reported in the previous study by Robertson *et al.* (2000) (10.66 g water/g citrus fiber) and Lario *et al.* (2004) (9.77 g water/g grape fiber). The increase in WHC with increase in particle size observed here was also reported for lemon fibers. Due to the high soluble fiber content of citrus fibers, dry milling affects its physical structure thereby breaking pores, increasing fiber density and thus reducing WHC (Lario *et al.*, 2004).

**Water swelling capacity:** WSC values ranged from 11.79-11.99 $cm^3 g^{-1}$ dry fiber. There was no significant difference ($p<0.05$) in swelling capacity for the different particles sizes as shown in Table 2. These values were slightly higher than those reported by Figuerola *et al.* (2005) for fiber concentrates for; Valencia orange (6.11 mL $g^{-1}$ DM), Liberty apple (8.27 mL $g^{-1}$ DM), Fino 49 lemon (9.19 mL $g^{-1}$ DM) and ruby grape (8.02 mL $g^{-1}$ DM) but lower than (16.9-17.5 mL $g^{-1}$ DM) reported for cauliflowers by Femenia *et al.* (1997). These values exhibited by the fiber here could be related to the insoluble dietary fiber content. Structural characteristics and the chemical composition of the fiber influence the kinetics of water uptake. Surface tension strength facilitates holding of water in the capillary structures of fiber and thus influence water interaction with molecular components through hydrogen bonding or dipole forms (Lopez *et al.*, 1996).

**Oil holding capacity:** Fine particle powder <0.177 mm showed a significantly ($p<0.05$) higher OHC than particle sizes 0.177 mm and above as shown in Table 2. These values ranging from 1.23-1.42 g oil/g dry sample were within the range of fat adsorption capacity of concentrates from; grapes (1.2 g oil/g DM), Eureka lemon (1.3 g oil/g DM), granny smith apple (1.45 g oil/g DM) (Figuerola *et al.*, 2005) and 1.26-5.81 g $g^{-1}$ reported in artichoke (Lopez *et al.*, 1996). Fat adsorption capacity (FAC) depends on surface properties, overall charge density, thickness and hydrophobic nature of the fiber particle (Lopez *et al.*, 1996). This property may be useful in stabilization of foods with high fat percentage.

**Farinograph properties of citrus fiber incorporated wheat flours:** Water absorption and mixing properties of citrus by-product fiber incorporated wheat flours are summarized in Table 3. Water absorption of the citrus by-product fiber incorporated flours increased compared to the control flour (without citrus by-product fiber) and the amount of water increase, increased with fiber increase. This could be due to insoluble dietary fiber structural characteristics and the chemical composition especially surface tension strength and hydrogen bonding (Lopez *et al.*, 1996). Studies have shown that addition of 30% hydroxypropylated wheat starch to wheat flour as well

Table 2: Physical properties of citrus by-product dietary fiber

| Treatment (mm) | WHC (g water/g dry sample) | WSC ($cm^3$/g dry sample) | OHC (g oil/g dry sample) |
|---|---|---|---|
| Particle size <0.177 | 5.08±0.17[a] | 11.98±0.27[a] | 1.42±0.05[b] |
| Particle size 0.177 | 5.97±0.08[b] | 11.79±0.36[a] | 1.26±0.06[a] |
| Particle size >0.250 | 6.44±0.05[c] | 11.99±0.29[a] | 1.23±0.06[a] |

Means±standard deviation of 3 replicates, Values followed by different letters in the same column are significantly different at $p<0.05$. WHC: Water holding capacity, WSC: Water swelling capacity, OHA: Oil holding capacity

Table 3: Effect of adding citrus by-product fiber on dough mixing characteristics

| Treatment | Water absorption index (g/100 g) | Dough stability (min) | Dongh development time (min) | Arrival time (min) | Breakdown (min) |
|---|---|---|---|---|---|
| Control | 65.3 | 12.7 | 10.2 | 1.4 | 14.0 |
| 1% | 68.0 | 11.8 | 8.7 | 1.6 | 13.4 |
| 2% | 70.6 | 10.5 | 7.8 | 1.6 | 12.1 |
| 3% | 73.6 | 10.7 | 8.8 | 2.4 | 13.0 |
| 3% pectin | 74.4 | 10.5 | 8.3 | 2.3 | 12.9 |
| 5% | 75.0 | 7.7 | 5.6 | 4.6 | 10.3 |

as substitution of 10-30% of wheat flour with hydroxypropylated cross-linked potato starch increases water absorption as compared to control (Miyazaki *et al.*, 2008).

Development times of citrus by-product fiber were shorter than the control (wheat flour without citrus by-product fiber). This seems to relate to the water swelling capacity of the citrus by-product dietary fiber where higher amount of water absorption tends to shorten development time. This behavior was reported by Miyazaki *et al.* (2008) for hydroxypropylated tapioca starch and phosphorylated cross-linked tapioca starch substituted wheat flours.

Dough stability showed a decreasing trend from 12.7 min for control to 7.7 min for 5% formulation Table 3. This could be attributed to effect of citrus fiber on the gluten cross-linking network with increase in the fiber content. The arrival time which indicated the rate of flour hydration increased from 1.4 min for control to 5.6 min for 5% formulation. This could be attributed to water hydration properties of the fiber. As discussed earlier, citrus fiber had a fairly good water hydration capacity.

## Properties of frozen dough bread made from citrus by-product incorporated wheat flours

**Bread volume:** Table 4 shows properties of frozen dough bread made from incorporation of different proportions of citrus by-product in to wheat flour. The Specific Volumes (SV) for the citrus by-product incorporated breads were lower than the control bread. It ranged from 1.82-3.15 compared to 3.41 for the control. Some of the values were in the range of 1.66-2.81 mL $g^{-1}$ reported by Yi and Kerr (2009) for breads made from dough prepared at different freezing rates and storage temperatures.

Bread SV decreased with increase in the amount of added fiber where, 1% formulation had SV of 3.15 while 5% formulation had 1.82. There was no significant difference ($p<0.05$) in SV between control and 1%, however, there were significant difference ($p<0.05$) between the rest of the incorporations and the control bread. The decrease in SV could be attributed to effect of freezing and fiber addition onto gluten network formation. Selomulyo and Zhou (2007) noted that the formation of ice crystals in non fermented dough stored for 24 weeks had disruptive effect on gluten matrix. Such disruptions were characterized by less continuous and more ruptured gluten network with poor gas retention during baking. This may explain why the loaf volume decreased in this study. As a quality factor, very small SV gives a very compact and closed grain structure in bread, while too large values gives a very open grain structure (Sharadanant and Khan, 2003). This may negatively affect the acceptability of such product by the consumers.

Table 4: Properties of wheat and citrus by-product fiber incorporated breads

| | | | | Properties | | |
|---|---|---|---|---|---|---|
| Substitution | Volume | SV | Bread Firmness | L* | a* | b* |
| Control | $398.33\pm32.15^{c}$ | $3.41\pm0.27^{c}$ | $360.31\pm1.83^{a}$ | $75.97\pm1.07^{b}$ | $0.91\pm0.65^{a}$ | $18.39\pm0.66^{b}$ |
| 1% Citrus | $368.33\pm16.07^{c}$ | $3.15\pm0.14^{c}$ | $366.83\pm1.48^{b}$ | $76.69\pm1.62^{b}$ | $1.47\pm0.37^{a}$ | $18.53\pm0.62^{b}$ |
| 2% Citrus | $293.32\pm5.770^{b}$ | $2.37\pm0.05^{b}$ | $372.72\pm0.87^{c}$ | $76.34\pm0.87^{b}$ | $1.28\pm0.30^{a}$ | $18.44\pm1.30^{b}$ |
| 3% Citrus | $250.00\pm27.84^{a}$ | $2.21\pm0.23^{b}$ | $384.01\pm1.69^{d}$ | $74.62\pm1.31^{ab}$ | $2.36\pm0.30^{bc}$ | $19.2\pm0.57^{b}$ |
| 3% Pectin | $260.00\pm17.32^{a}$ | $2.09\pm0.13^{ab}$ | $497.26\pm0.85^{e}$ | $77.11\pm1.81^{b}$ | $1.72\pm0.39^{ab}$ | $16.47\pm1.32^{a}$ |
| 5% Citrus | $223.33\pm5.770^{a}$ | $1.82\pm0.05_{a}$ | $804.52\pm0.72^{f}$ | $72.21\pm1.46^{a}$ | $3.03\pm0.59^{c}$ | $20.93\pm0.45^{c}$ |

Means±standard deviation of 3 replicates, Values followed by different letters in the same column are significantly different at $p<0.05$.
SV: Specific volume of the bread, L*: Lightness, a*: Redness, b*: Yellowness

**Bread firmness:** Crumb firmness for the control bread and fiber incorporated breads are shown in Table 4. The result showed that, incorporation of fiber formulations resulted in linear increase in bread firmness. The control bread had firmness of 360.31 N while those of citrus by-product incorporated breads ranged from 366.83-804.52 N. There was significant difference ($p<0.05$) in bread firmness between control and all the citrus by-product incorporated breads. The increased firmness was attributed to the effect of fiber on the gluten network as evident in reduced specific volume. Selomulyo and Zhou (2007) noted that, starch granule damaged during ice recrystallization affected proteins in the dough and thus lowering gas properties. Although high soluble fiber and protein are reported to reduce bread firmness (Mohamed *et al*., 2010), the observed trend here could be attributed to a significant high amount of IDF (53.07 g/100 g) compared to SDF (17.97 g/100 g) found in citrus by-product dietary fiber used in the blends.

**Crumb color:** Bread golden brown crust and creamy white crumb are suppose to be uniform and appealing and is an important indicator of bread quality (Yi and Kerr, 2009). In this study, bread color parameters; L*, a* and b* were determined for lightness, redness and yellowness respectively and are summarized in Table 4. The L* for control was 75.97 while those of citrus by-product incorporated breads ranged from 72.21 for 5% incorporation to 77.11 for 3% refined pectin incorporation. There was no significant difference ($p<0.05$) between the control and the different incorporations except for 5% incorporation which had the lowest value for L*. The a* value for control was 0.91 and the lowest while the citrus by-product incorporated values ranged from 1.28 to 3.03. There was a significant difference ($p<0.05$) in a* value between control and 3% citrus, 3% pectin and 5% citrus whereas the rest showed no significant difference. The b* value for control was 18.39 while those of the incorporations ranged from 16.47 to 20.93 with only 3% pectin and 5% citrus incorporations showing a significant difference ($p<0.05$) from the control.

**Dietary fiber content of bread:** The fiber content of the breads is shown in Fig. 1. The result showed that the addition of citrus by product fiber resulted in increase in total dietary fiber content of the bread with 5% formulations having the highest amount. This could be one of the factors responsible for the decreased trend seen in bread volume. Sabanis *et al.* (2009) noted that breads

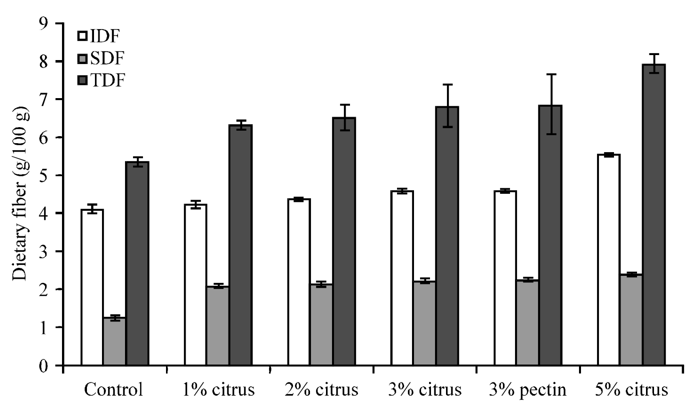


Fig. 1: Showing insoluble dietary fiber (IDF), soluble dietary fiber (SDF) and total dietary fiber (TDF) composition of control bread and different citrus by-product formulation breads (1% citrus fiber, 2% citrus fiber, 3% citrus fiber, 3% citrus refined pectin and 5% citrus fiber breads)

Table 5: Sensory evaluation of bread made from citrus by-product substituted wheat flour

| Parameters | Control | 1% | 2% | 3% | 3% pectin | 5% |
|---|---|---|---|---|---|---|
| Color and appearance | 7.89±0.88[d] | 7.68±0.75[d] | 7.16±0.60[d] | 6.26±1.19[c] | 5.16±1.12[b] | 4.26±1.76[a] |
| Texture | 7.58±0.84[c] | 7.37±0.90[c] | 7.16±0.96[c] | 6.32±0.75[b] | 5.63±1.26[b] | 4.47±1.81[a] |
| Flavor | 7.37±0.83[c] | 7.42±1.17[c] | 7.47±1.31[c] | 4.95±1.43[b] | 4.63±1.54[ab] | 3.95±2.21[a] |
| Overall acceptability | 7.63±0.96[d] | 7.53±0.91[d] | 7.21±0.85[d] | 6.21±0.92[c] | 5.42±0.90[b] | 4.47±2.12[a] |

Means±standard deviation of 3 replicates, Values followed by different letters in the same row are significantly different ($p < 0.05$)

baked with added wheat fiber had smaller loaves, dense tightly packed crumb structure with a higher crumb firmness value. This might have been due to thickening of the walls surrounding air bubbles in the crumb. The nutritional importance of DF has been demonstrated in many studies and the recommended daily intake is 25-30 g (Sabanis *et al.*, 2009). The 5% formulation had a total dietary content of 7.92 g/100 g with SDF content of 2.39 g/100 g. This is very important considering the fact that higher SDF/IDF ratio or high SDF content fiber possess a high nutritional value (Vitaglione *et al.*, 2008). This has indicated that addition of citrus fiber in bread will improve the nutrition value as well as improving the health benefit of such a product.

**Sensory evaluation:** The effect of incorporation of citrus by-product fiber on the sensory properties and overall acceptability score are shown in Table 5. For color and appearance, addition of the fiber was quite acceptable at low levels of citrus fiber formulations comparable to the control, with only 5% formulation receiving low score. There was no significant difference between control bread, 1 and 2% formulations (score of 7.89, 7.68 and 7.16, respectively).The low score by 5% formulation could be due to visibly fibrous appearance with compact and less air spaces in the crumb structure.

For texture, panelist liked by scoring highly and commented that the breads had fine uniform crumb texture with small pore sizes, light brown color and fresh appearance. Control bread had highest score of 7.58 but was not significantly different from 1% and 2% formulations (Score of 7.37 and 7.16). The least like texture was 5% formulations with score of 4.47, probably because of the visibly less fine texture.

All formulations were accepted except 5% formulation which had score less than 5. The control was the most acceptable sample followed by 1, 2, 3 and 3% pectin formulations. However, with regards to flavor, panelist liked 2% formulation most followed by 1% and control with a score of 7.47, 7.42 and 7.37, respectively. This could be attributed to the rich fruity flavor at low levels of fiber addition which was quite acceptable. However, at higher levels of formulations of 3% and above, the flavor was not much acceptable probably due to much stronger fruity flavor.

## CONCLUSION

Addition of citrus by-product fibers in frozen dough formulations gave breads with comparable volume to that of the control at low concentration formulations but reduced bread volumes at concentrations above 2% significantly. All the breads showed higher amounts of soluble dietary fiber as well as total dietary fiber. The sensory analysis result showed that there were no significant difference ($p<0.05$) in overall acceptability of breads between control and formulations consisting of 1 and 2% citrus by-product fiber. However, both citrus by-product formulation had higher scores for flavor acceptability especially 2% formulation than the control. This study has shown that there is a significant potential for production of fresh citrus by-product fiber rich breads from frozen dough with a highly acceptable citrus flavor at low levels of blends. This can significantly provide a continuous supply of fresh and high content dietary fiber content rich breads to consumers.

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