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Effect of Resistant Starch on Physicochemical Properties of Wheat Dough and Bread

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Abstract The effect on the baking performance of dough and bread of adding resistant starch in proportions of 0-30% as a substitute for bread flour was investigated. Resistant starch had significant effect ($p<0.05$) on dough, decreasing the farinograph water absorption; changing the peak viscosity, peak time, holding strength, and final viscosity as measured by a Rapid Visco Analyzer; and also changing the Alveography P-value and W-value. This indicates that an increased level of resistant starch has a destructive effect on the formation of the gluten network. Dilution of the wheat proteins resulted in a lighter crumb color. The microstructure of crumbs with a high proportion of resistant starch (30%) showed less structural integrity and a coarser network structure. The specific volume of bread made with 20% and 30% resistant starch was significantly lowered ($p<0.05$). Bread made with 10% resistant starch received the highest overall acceptability rating by a sensory panel, and this should be taken into consideration by bakery processors when resistant starch is added to bread.

Keywords: *alveograph, bread, farinograph, resistant starch, scanning electron microscopy (SEM)*

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1. Introduction

Carbohydrates are the main dietary energy source for human consumption. They account for 45-70% of total human energy intake [1]. Bread contributes the highest proportion of carbohydrates in European dietary intake [2]. Particularly whole-grain breads are an important source of dietary fiber [3,4]. Dietary fiber offers health benefits including reduction of post-prandial blood glucose level, total and/or LDL cholesterol levels of blood, and intestinal transit time; furthermore, it is fermentable by colonic microflora and increases stool bulk [5]. Five forms of resistant starch have been recognized as dietary fiber and functional ingredients in food [6,7].

Resistant starch is a fine, white power that is more acceptable to consumers in terms of taste and color than traditional sources of dietary fiber [6]. Nevertheless, the addition of resistant starch dilutes dough gluten, thereby inducing poor rheological characteristics, diminished process efficiency, and undesirable bread qualities [8,9].

The objective of our work was to determine the optimal blend proportions of composite bread flours made from 0 to 30% resistant starch. The optimum composite formulation should lead to the maximum specific bread volume for the maximum level of bread flour substitution. The results can provide valuable information towards the development of bread products with a higher content of added resistant starch.

2. Materials and Methods

2.1. Raw Materials and Chemicals

Bread flour was purchased from Uni-President Enterprises Corporation (Tainan, Taiwan). Shortening (OAL21407) was purchased from Namchow Group (Taoyuan, Taiwan). Instant dry yeast was purchased from Yung Cheng Industries Ltd. (Taipei, Taiwan). Resistant starch (Fibersym™70) was purchased from MGP Ingredients, Inc. (Atchison, Kansas, USA). The baking formulae based on baker's percentages are shown in Table 1 and water content was determined from a farinograph absorption test (Jen Dah Food Machinery, Chiayai, Taiwan). All the ingredients except the shortening were combined and mixed into a dough using an electric mixer (Jen Dah Food Machinery) according to AACC [10] Method 10-10B. The shortening was added after the dough had developed (8 min at intermediate speed of the mixer), and the dough was mixed for a further 12 min. The dough was then fermented for 50 min at a temperature of 26°C and relative humidity of 85%. The dough was divided and rounded into approximate spheres (450 g dough for additional fermentation for 10 min at room temperature of 25°C). The molded dough was fermented in the final proof room for a further 50 min at a temperature of 38°C and relative humidity of 85%, then baked in an electric oven (Jen Dah Food Machinery) at 150°C/200°C for 30-35 min. Loaf volume was measured immediately after baking by the rapeseed displacement method. Specific volume (cm^3/g) was calculated as loaf volume divided by loaf weight.

Table 1. Formulae of bread dough with different proportions of added resistant starch

Ingredient	Control (%)	RS10 (%)	RS20 (%)	RS30 (%)
Bread flour	100	90	80	70
Resistant starch	0	10	20	30
Water	63.9	61.5	58.4	57.2
Instant yeast	1.8	1.8	1.8	1.8
Sugar	6	6	6	6
Salt	1.5	1.5	1.5	1.5
Shortening	3	3	3	3

RS10: 10% resistant starch, RS20: 20% resistant starch, RS30: 30% resistant starch.

Farinographs (C. W. Brabender Instruments, Inc., South Hackensack, NJ, USA) were run at 30°C with bread dough made from 300 g bread flour with water added to center at 500 Brabender Units by adjusting dough water content. The amounts of water added to 0%, 10%, 20%, and 30% resistant-starch dough were 63.9%, 61.5%, 58.4%, and 57.2%, respectively. By this means, flour water absorption, arriving time, departure time, stability, and peak time were determined by following AACC [10] Method 54-21.

The viscoamylographs of these four flours were determined using a Rapid Visco Analyzer model 3D (RVA) (Newport Scientific Pty Ltd., Warriewood, Australia) following the method of Whalen et al. [11]. The RVA 3D was operated with 3.5 g bread flour, 25 ml water, and 10%, 20%, and 30% resistant starch substituted for bread flour. The temperature profile included a 1 min isothermal step at 50°C, a linear temperature increase to 95°C in 3.75 min, a holding step (2.5 min at 95°C), and a cooling step (3.75 min) with a linear temperature decrease to 50°C. The RVA pasting parameters of peak viscosity, trough, breakdown, peak time, pasting temperature, final viscosity, and setback were measured in triplicate.

2.2. Dough Expansion

The dough expansion test followed the method of Hwang et al. [12]. After mixing, dough was divided into 30 g pieces and rounded. Dough samples were inserted one each into 250 ml graduated cylinders, which were placed in a cabinet at a temperature of 28°C and relative humidity of 75% for 240 min. Dough volume was recorded every 15 min.

2.3. Scanning Electron Microscopy

Bread was examined followed the methods of Kim et al. [13]. Bread samples were freeze-vacuum-dried at -50°C for 24 hours. Freeze-dried bread was cut with a razor blade into 0.8 × 0.8 × 0.3 cm crumbs that were mounted onto brass stubs using silver glue. Then the samples were freeze-vacuum-dried at -50°C once more for 48 hours. A gold coating was applied using a sputter coater (LADD No. 30800, Sputter Coater, Burlington, Vermont, USA). Samples were examined at 20 KV using a Hitachi S-2500 Scanning Electron Microscope (Tokyo, Japan).

2.4. Texture Properties of Bread

Bread loaves were sealed in 1 kg polyethylene (PE) bags after baking for 1 hour and held at room temperature (25°C) for further testing. Loaves were sliced into 2 × 2 × 2 cm crumbs using a standard bread slicer. Hardness, springiness, cohesiveness, and chewiness of breads were tested with a TA.XT2 Texture Analyzer (Stable Micro Systems Co., Ltd., Vienna Court, Godalming, UK) and a 1/2” diameter cylinder probe (No. P/0.5S) according to the methods of Hwang et al. [12]. Texture profile analysis (TPA) was conducted with a test speed of 5.0 mm/s (50% strain, 10 mm). The calibration distance for the probe was 25 mm.

2.5. Sensory Evaluation

Bread samples were served to 50 panelists to evaluate aroma, mouth feel, and overall acceptability. Panelists were instructed to evaluate each attribute using a nine-point hedonic scale ranging from “dislike extremely = 1” to “like extremely = 9”. Bread samples coded with three digits were supplied to them. Each data point from the sensory analysis represents the average of 50 panelists’ scores.

2.6. Statistic Analysis

Data were analyzed by analysis of variance programs using the SPSS statistics program for Windows Version 12 (SPSS Inc., Chicago, IL, USA). Ducan’s new multiple range test was used to identify differences between treatments at a 5% significance level ($p<0.05$).

3. Results and Discussion

Table 2 shows that the farinograph water absorption of flour decreased with higher resistant starch content up to the 30%. The water absorption of bread flour depends on the protein, the pentosan content, and presence of mechanically damaged starch granules in the wheat [14]. The lowered level of water absorption of composite flours containing resistant starch could be due to a lower content of proteins and pentosans. The development time of composite dough containing 10% resistant starch was close to that of the controls (Table 2), but this time fell notably when the level of bread flour substitution was 30% (Table 2). Gluten, the skeleton of wheat flour dough, is formed when wheat flour is mixed with water. This hydrated complex protein plays a significant role in gas retention of leavened products [15]. Dough stability and time to breakdown indicate how much additional mixing can be imparted to dough before the dough begins to break down [15]. A higher stability and a longer dough development time and time to breakdown indicate higher flour strength and stronger dough [16]. It takes longer for a stronger flour to develop before reaching the 500 Brabender Unit (BU) level. In contrast, a weaker flour shows a dramatic decline in viscosity and its dough cannot withstand mixing after developing. A quick breakdown of the gluten network over 5 min of mixing after the peak was evident in the mixing tolerance index values when 30% resistant starch was added (Table 2).

Composite flour with 30% resistant starch showed a significantly lower pasting temperature, peak viscosity, peak time, holding strength, and final viscosity than those of control (Table 3). Pasting temperature is an index of the minimum temperature required to gelatinize the composite flour. The lower RVA peak values observed in the resistant-starch-substituting bread flours indicate reduced swelling of the starch granules compared to normal. The resistant starch used (Fibersym ™70) is derived from wheat, potatoes, and high-amylose corn. Amylose is considered to maintain starch granules, integrity and to suppress swelling [17]. Breakdown viscosity refers to peak viscosity minus holding strength, and it implies shear and rupturing of swollen starch granules. The present study showed that the resistant starch of the composite flour did not become disrupted and gelatinized to increase peak viscosity. Setback viscosity is final viscosity minus holding strength and it refers the degree of retrogradation of gelatinized starch. The setback and final viscosity may be related to a greater association of amylose to the degree of polymerization of the amylose fraction leached during swelling [18]. However, starch retrogradation was not correlated with the resistant starch content of the composite flours used in this study. This may be due to the fact that the resistant starch did not swell at all during baking.

The substitution of resistant starch for bread flour decreased the overpressure (P value) and dough tenacity (P) of the composite dough needed to retain gas as shown in Table 4. The P value, curve configuration ratio (P/L), and energy deformation (W) of the bread flour dough decreased as the energy (W) proportion of resistant starch increased from 0% to 30% and made the dough softer (Table 4).

Resistant starch alone does not exhibit any gluten-like properties. As the proportion of resistant starch increased in the composite dough, it might have diluted the gluten concentration and lead to a weakening of tensile properties such as resistance to extension and extensibility.

As illustrated in Figure 1, the dough volume increase of bread dough with 10% resistant starch was similar to that of the controls. Dough with 20% and 30% resistant starch substituted for bread flour, on the other hand, were obviously unable to retain the CO_2 generated by the yeast. This is possibly due to their containing less gluten. Dough made from bread flour with 10% resistant starch had a faster volume increase during the first 60 min than those with 20% and 30% resistant starch (Figure 1). All treatments showed a slow volume increase after 60 min fermentation time. Again, probably because of the diluted gluten content of the dough the final volume of dough with 30% resistant starch substitution was significantly lower than other treatments (Figure 1).

Table 2. Effect of resistant starch addition on Farinography parameters of dough

Resistant starch (%)	Water absorption (%)	Development time (min)	Stability (min)	Tolerance index(MIT)	Time to breakdown(min)
0	63.9±0.0 [a]	14.4±0.5 [c]	19.5±1.1 [cd]	22±2.8 [bc]	22.1±0.1 [b]
10	61.5± 0.1 [c]	14.6±0.9 [bc]	18.9±0.9 [d]	23±0.7 [b]	21.7±0.6 [b]
20	58.4±0.1 [f]	12.9±0.6 [d]	20.9±0.6 [abc]	16±2.8 [c]	22.7±0.3 [ab]
30	57.2±0.1 [g]	1.5±0.1 [e]	15.4±0.2 [e]	59±3.5 [a]	2.5±0.1 [c]

Values are mean ± SD, n=3.
Different letters in the same column indicate significant differences (p<0.05).

Table 3. Effect of resistant starch addition on Rapid Visco Analyzer (RVA) pasting properties of dough

Resistant starch (%)	Pasting temperature (°C)	Peak viscosity (RVU)	Peak time (min)	Holding strength (RVU)	Final viscosity (RVU)
0	64.2±0.1 [ab]	219±0.7 [a]	6.2±0.1 [a]	140±1.4 [a]	254±0.7 [a]
10	64.2±0.1 [ab]	173±2.8 [b]	6.1±0.1 [a]	113±2.1 [b]	207±0.0 [b]
20	64.4±0.4 [ab]	127±2.1 [d]	5.8±0.0 [b]	84±1.4 [d]	164±3.5 [c]
30	61.1±0.1 [c]	90±2.1 [e]	5.5±0.1 [c]	62±2.1 [e]	123±2.1 [d]

Values are mean ± SD, n=3; RVU: Rapid Visco unit
Different letters in the same column indicate significant differences (p<0.05).

Table 4. Effects of resistant starch addition on Alveograph parameters of dough.

Resistant starch (%)	P (mm-H_2O)	L (mm)	P/L	W (10^{-4}joule)
0	102±4.2 [a]	106±3.5 [ab]	0.97 ±0.07 [a]	442±9 [a]
10	85±0.7 [cd]	118±6.4 [a]	0.72±0.03 [cd]	389±19 [b]
20	72±0.7 [e]	106±5.0 [ab]	0.68±0.04 [cd]	300±8 [d]
30	61±1.4 [f]	100±12 [b]	0.62±0.08 [d]	235±17 [e]

Values are mean ± SD, n=3
Different letters in the same column indicate significant differences (p<0.05).

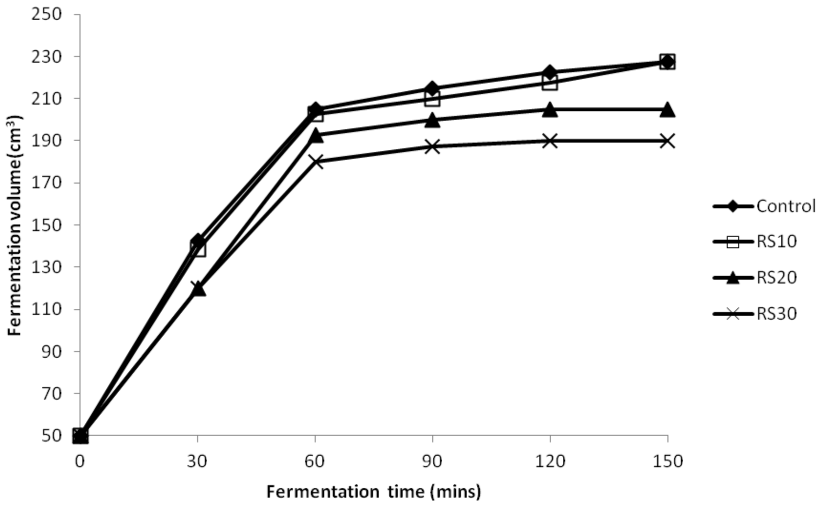

Figure 1. Effect of resistant starch addition on volume of fermenting dough. RS10, RS20, and RS30 with 10%, 20%, and 30% resistant starch, respectively

3.1. Texture Properties of Breads

The texture properties of crumbs containing resistant starch at the 20% level were significantly different ($p<0.05$) from those of the controls and 10% resistant starch substituted bread, but lower levels of resistant starch did not appreciably affect the texture of the bread. Hardness and chewiness increased with resistant starch addition, while springiness and cohesiveness decreased (Table 5). Texture properties were not significantly different ($p>0.05$) between the control bread and bread with 10% resistant starch. The substitution of resistant starch for flour at the 10% level does not change the texture properties and baking quality of resistant starch breads. Altuna et al. [19] found that partial substitution of wheat flour by resistant starch (12.5 g/100 g) produced bread with a higher crumb firmness than regular dough did. Specific volume decreased as the proportion of resistant starch increased above 20% (Table 6). There was no significant difference ($p>0.05$) in the specific volume control bread and bread with 10% resistant starch, so this level of substitution might be a good choice for the application of resistant starch in bread-making.

Substitution of 30% of the flour by resistant starch had a significant effect ($p<0.05$) on the lightness (L), red content, and white index of bread crumbs, but not the yellow content (Table 6). Lightness content and white index increased as the proportion of resistant starch increased. Dilution of the wheat proteins resulted in a less colored crumb. The same sorts of color difference in comparison to regular bread have been noticed in bread crust produced with resistant starch [19]. The browning of the crust during baking occurs due to the Maillard reaction, which involves the interaction of free reducing sugars with free amino groups from protein [20]. Less protein means fewer free amino groups, and therefore less browning.

The gas cells of bread made with 30% resistant starch were irregularly larger than those of control bread (Figure 2). The microstructure of crumbs with a high proportion of resistant showed less structural integrity and a coarser network structure. The overall acceptability and mouth feel scores of the test breads decreased significantly ($p<0.05$) at the 30% substitution level as compared to the control bread (Table 7). No significant ($p>0.05$) differences were found in aroma.

Table 5. Effect of resistant starch addition on Texture Profile Analyzer parameters

Resistant starch (%)	Hardness (g)	Springiness	Cohesiveness	Chewiness (g)
0	191.07±42.45^{a}	0.98±0.00^{a}	0.88±0.01^{a}	161.76±32.10^{a}
10	229.22±65.72^{a}	0.98±0.00^{a}	0.87±0.03^{a}	190.79±50.63^{ab}
20	327.82±66.31^{b}	0.96±0.00^{b}	0.83±0.03^{b}	258.55±50.65^{b}
30	498.08±41.94^{c}	0.96±0.01^{b}	0.79±0.02^{b}	373.86±32.68^{c}

Values are mean ± SD, n=3
Different letters in the same column indicate significant differences ($p<0.05$).

Table 6. Effect of resistant starch addition on the specific volume and color of bread crumbs

Resistant starch (%)	Specific volume (cm^3/g)	L	a	b	White Index
0	5.14^{a}	51.93±7.89^{a}	18.62±0.11^{a}	34.69±5.78^{a}	37.39±3.27^{a}
10	5.13^{a}	57.17±6.54^{ab}	18.43±0.90^{ab}	37.86±2.50^{a}	39.69±3.31^{a}
20	4.82^{b}	63.53±5.57^{ab}	16.06±0.84^{b}	38.32±1.89^{a}	44.53±2.79^{ab}
30	4.6^{c}	69.39±5.51^{b}	13.80±2.30^{b}	36.86±2.39^{a}	49.98±5.09^{b}

Values are mean ± SD, n=3
Different letters in the same column indicate significant differences ($p<0.05$)
White Index (WI) = $100- [(100-L)^2+(a)^2+(b)^2]^{1/2}$.

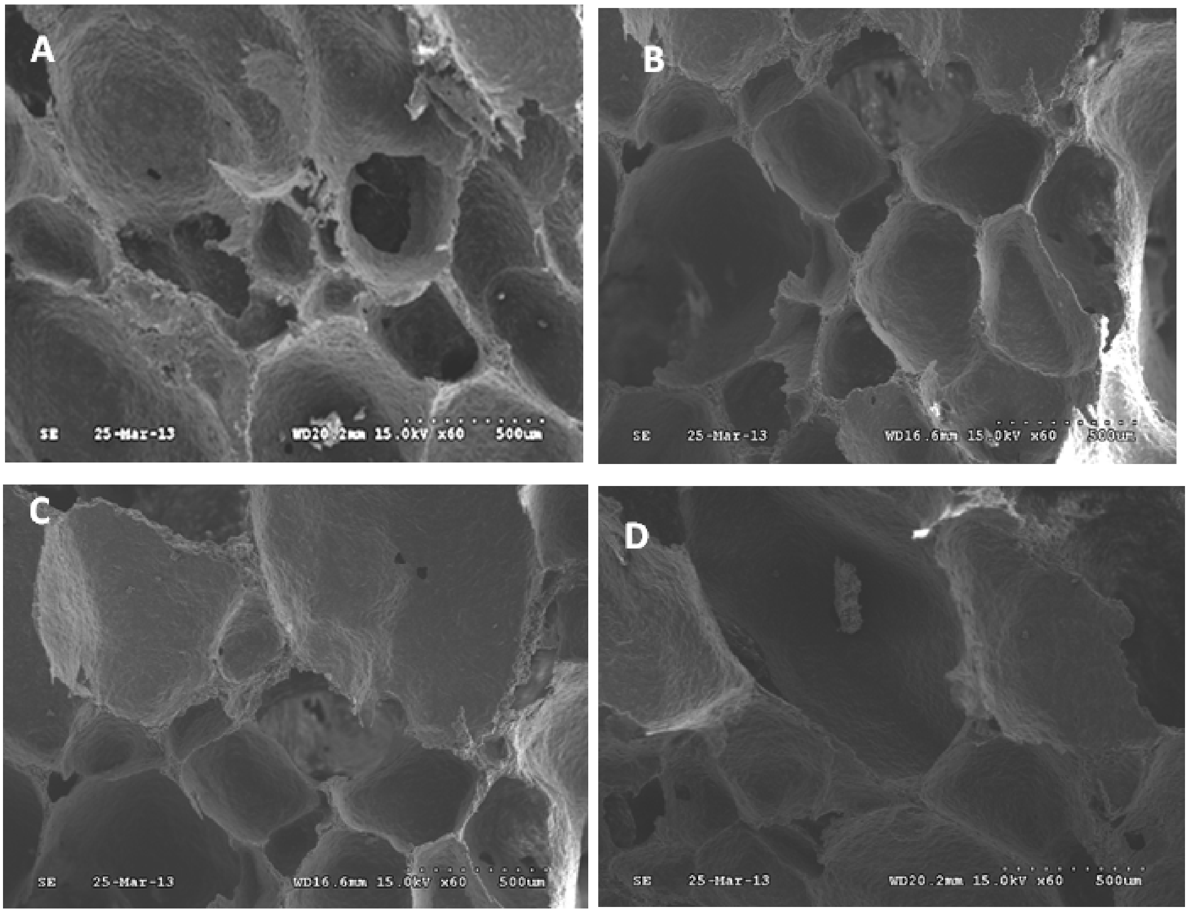

Figure 2. Scanning electron micrographs of bread crumbs with different proportions of resistant starch (A: Control; B: 10% (RS10); C: 20% (RS20); D: 30% (RS30)

Table 7. Sensory evaluation of bread with different resistant starch content, graded on a scale of 0 to 5

Resistant starch (%)	Aroma	Mouth feel	Overall acceptability
0	3.2^{a}	3.2^{ab}	3.4^{a}
10	3.4^{a}	3.5^{a}	3.5^{a}
20	3.2^{a}	3.0^{bc}	3.0^{b}
30	3.1^{a}	2.8^{c}	3.0^{b}

Values are mean ± SD, n=3; a nine-point hedonic scale ranging from “dislike extremely = 1” to “like extremely = 5”.
Different letters in the same column indicate significant differences ($p<0.05$).

4. Conclusion

Our results show that resistant starch can be substituted at a 10% level in bread flour without any detrimental effect on various bread qualities. Lightness content and white index of bread crumbs increased. The dilution of the wheat gluten resulting from this substitution resulted in a lighter crumb color, lower farinograph water absorption, Rapid Visco Analyzer peak time, peak viscosity, holding strength, and final viscosity of flour paste, dough Alveography P-value and W-value and the specific volume of the baked bread.

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References

[1] Lafiandra, D., Riccardi, G., and Shewry, P.P., “Improving cereal grain carbohydrates for diet and health,” *Journal of Cereal Science*, 59(3). 312-326. 2014.

[2] Cust, A.E., Skilton, M.R., van Bakel, M.M., Halkjaer, J., Olsen, A., Agnoli, C., et al., “Total dietary carbohydrate, sugar, starch and fibre intakes in the European prospective investigation into cancer and nutrition,” *European Journal of Clinical Nutrition*, 63 (Suppl 4). S37-S60. 2009.

[3] Khalid, K.H., Ohm, J.B., and Simsek, S., “Whole wheat bread: Effect of bran fractions on dough and end-product quality,” *Journal of Cereal Science*, 78. 48-56. 2017.

[4] Lattimer, J.M., and Haub, M.D., “Effects of dietary fiber and its components on metabolic health,” *Nutrients*, 2(12). 1266-1289. 2010.

[5] FAO/WHO Codex Alimentarius Comission. Report of the 30th session of the Codex committee on nutrition and foods for special dietary uses.2009. From http://www.codexalimentarius.org/.

[6] Fuentes-Zaragoza, E., Riquelme-Navarrete, M.J. Sanchez-Zapata, E., and Perez-Alvarez, J.A., “Resistant starch as a functional ingredient: A review,” *Food Research International*, 43(4). 931-942. 2010.

[7] Chung, H.J., Donner, E., and Liu, Q., "Resistant starches in foods," *Comprehensive Biotechnology*, 4. 527-534. 2011.

[8] Almeida, E.L., Chang, Y.K., and Steel, C.J., "Dietary fibre sources in bread: Influence on technological quality," *LWT-Food Science and Technology*, 50(2). 545-553. 2013.

[9] Sanchez, P.B.O., Puppo, M.C., Anon, M.C., Ribotta, P.D., Leon, A.E., and Tadini, C.C., "Effect of maize resistant starch and transglutaminase: A study of fundamental and empirical rheology properties of pan bread dough," *Food and Bioprocess Technology*, 7. 2865-2876. 2014.

[10] AACC. *Approved Methods of the American Association Cereal Chemists*. 10th ed. Methods 10-10B, 54-21 St. Paul, MN, USA, 2000.

[11] Whalen, P.J., Bason, M.L., Booth, R.I., Walker, C.E., and Williams, P.J., "Measurement of extrusion effects by viscosity profile using the Rapid Visco Analyser," *Cereal Foods World*, 42. 469-475. 1997.

[12] Hwang, J.Y., Sung, W.C., and Shyu, Y.S., "Effect of mulberry lees addition on dough mixing characteristics and the quality of mulberry toast," *Journal of Marine Science and Technology*, 16(2). 103-108. 2008.

[13] Kim, H.J., Mortia, N., Lee, S.H., and Moon, K.D., "Scanning electron microscopic observations of dough and bread supplemented with *Gastrodia elata* Blume powder," *Food Research International*, 36(4). 387-397. 2003.

[14] Guttieri, M.J., Bowen, D., Gannon, D., O'Brien, K., and Souza, E., "Solvent retention capacities of irrigated soft white spring wheat flours," *Crop Science Journal*, 41(4). 1054-1061.2001.

[15] Nindjin, C., Amani, G.N., and Sindic, M., "Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality," *Carbohydrate Polymers*, 86(4). 1637-1645.2011.

[16] Wang, J., Rosell, C.M., and Benedito de Barbera, C., "Effect of the addition of different fibres on wheat dough performance and bread quality," *Food Chemistry*, 79(2). 221-226.2002.

[17] Sasaki, T., "Effect of wheat starch characteristics on the gelatinization retrogradation, and gelation properties," *Japan Agricultural Research Quarterly*, 39(4). 253-260. 2005.

[18] Chung, H.J., Jeong, H.Y., and Lim, S.T., "Effects of acid hydrolysis and defatting on crystallinity and pasting properties of freeze-thawed high amylase corn starch," *Carbohydrate Polymers*, 54(4). 449-455. 2003.

[19] Altuna, L., Ribotta, P.D., and Tadini, C.C., "Effect of a combination of enzymes on dough rheology and physical and senory properties of bread enriched with resistant starch, *LWT-Food Science and Technology*, 64(2). 867-873. 2015.

[20] Pyler, E.J., and Gorton, I.A., Baking science & technology. In Formulation & production (4th ed., Vol. II.) (Chapter 6). Sosland Publishing Co. Kansas.2009.