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RHEOLOGICAL, CHEMICAL AND FUNCTIONAL IMPACTS OF ALCOHOL INSOLUBLE RESIDUE FROM POTATO PROCESSING BY-PRODUCT ENRICHED BREAD USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT: The aim of this study was to evaluate and optimize incorporation of alcohol insoluble residue from potato processing by-product (AIR-PPB) in wheat flour bread at different particle sizes by using response surface methodology (RSM). Results showed an improvement in the functional properties of the AIR-PPB in terms of water holding capacity (WHC), swelling capacity (SC) and water solubility index (WSI) as particle size increased. As portion of AIR-PPB and particle size increased, total dietary fiber content, water absorption (WA), dough development time (DDT) increased. Higher particle size giving more stability to the dough structure but had inverse effect on dough weakening (DW). Breads with lower specific volumes, higher hardness were associated with increment in AIR-PPB incorporation level at higher particle size. All the sensory attributes of experimental and control breads were acceptable.

Key words: Potato peel, *Solanum tuberosum*, alcohol insoluble residue, dietary fiber, bread, functional properties.

INTRODUCTION

Potatoes (*Solanum tuberosum* L.) are one of the most widely consumed vegetables in the world; consider the fourth main crop behind rice, wheat and maize. The global production represented 370 million tons. Egypt contributes by about 1.3% of the world potato production (5 million tons). (Wijesinha-Bettoni and Mouillé 2019). According to International Potato Center (2019), it is estimated that more than 50% of the total global production of potato is consumed after processing. The residue resulting from the processing of potato products represents about 15-40% of the fresh weight depending on the peeling method used (Schieber *et al.*, 2001). These wastes can cause serious environmental negative impacts if it left unused (Namir *et al.*, 2015).

Potato by-product is considered a high value waste as it is considered a source of bioactive

compounds such as phenolic compounds with considerable antioxidant activity (Albishi *et al.*, 2013; Friedman *et al.*, 2018), in addition it considered a source of dietary fiber, starch and proteins (Khawla *et al.*, 2014). Peels consider the predominant component in potato by-product (Farvin *et al.*, 2012). Based on that, potato peels were used in many applications, as it was used as animal feed (Schieber and Saldaña, 2009), as biomass sources (Osman, 2020). Furthermore, it used successfully in improving the functionality of several bakery products such as bread where it used to reduce bread staling for over 7 days of storage (Curti *et al.*, 2016) and reducing acrylamide content in quinoa flatbreads (Crawford *et al.*, 2019). Another study used potato peel powder in biscuit formulation by substituting wheat flour and observed an increase in water absorption, dough development time and dough stability, while increasing antioxidant activities and fiber

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content at the same time (Hallabo *et al.*, 2018). In addition, it was found that incorporation of potato peel to cake dough, improves the texture properties, increases the dough strength and elasticity to extensibility ratio, as well as the absence of organoleptic differences with the control sample (Jeddou *et al.*, 2017).

One of the important components of a healthy diet is the content of dietary fiber. Dietary fiber can be defined as an edible portion of plants composed of mixture of indigestible carbohydrate polymers of oligosaccharides and polysaccharides which can't be digested in the small intestine in humans. However, complete or partial fermentation of dietary fiber can occur in the large intestine (AACC, 2000). According to FAO/WHO expert consultation report (2001), adult person needs about 25-35 g of dietary fiber per day. The functionality of dietary fiber is presented through its ability to reduces insulin responses, blood cholesterol levels, risk of cardiac disease, cancer, obesity and diabetes (Lan *et al.*, 2012). Several previous works dealt with the incorporation of fiber-rich by products in food products as flour, sugar and fat substitute as it improved the texture, viscosity, sensory characteristics and extended shelf-life or used as thickening or emulsifier agents due to its ability to bind water and oil. Nevertheless, the portion of adding fiber to food mixtures remains limited to avoid undesirable changes in the texture, colour and taste of the supplemented food (Wang *et al.*, 2002; Sangnark and Noomhorm, 2004; Elleuch *et al.*, 2011; Kurek *et al.*, 2017; He *et al.*, 2021)

The objectives of this research were to extract fiber rich fraction of alcohol insoluble residue from potato peel by-product (AIR-PPB) and determine which extent a blend of AIR-PPB could be added to wheat flour at different particle size through rheological and chemical-functional attributes of resulted bread by using response surface methodology (RSM).

MATERIALS AND METHODS

Sample Preparation

Potato peel by-product (*Solanum tuberosum* L.) (PPB) was obtained as fresh by-product from Farm Frites Factory, 10th of Ramadan city,

Egypt. The obtained by-product was washed properly with distilled water. Water was drained and the PPB was allowed to dry in hot air oven at 45±2°C for 24 h. Dried PPB were then packed in Zip lock plastic bag and kept in refrigerator at 4±2°C till use.

Preparation of Alcohol Insoluble Residue (AIR)

The Alcohol insoluble residue (AIR) was separated from PPB according to the method described by Latorre *et al.* (2010) with slight modification. One hundred grams of dried PPB were mixed with 500 ml of 70% w/v of ethanol solution with stirring, and then boiled for 30 min. After centrifugation at 3000 rpm the supernatant was decanted and the residue was obtained and extracted twice with 500 ml of 95% w/v ethanol solution under boiling, for 30 min. The insoluble residue was separated and washed with 300 ml of acetone solutions and dried at 50°C overnight to remove acetone and re-weighed to determine the percentage of AIR which accounts 63.87. After drying, AIR was milled and sieved through standard sieves with a diameter of 40, 70, 145 and 250 mesh. AIR powder were packed in Zip lock Plastic Bag and stored at 4±2°C until further analysis.

Bread-making Process

For pan bread making, dough was prepared by the straight method. Sugar and yeast were dissolved in the warm water (30°C). Then the other dry ingredients including the wheat flour (72% extraction ratio) (The flour was replaced with AIR-PPB at the experimental range of 2-15% at particle sizes of 40-250 mesh which specified through preliminary experiments) and salt were added. Butter was melted and added to the mixture and then mixed using a spiral mixer for 3 min at low speed, followed by 6 min mixing at high speed. After that, dough was placed in the incubator at 30°C and 85% relative humidity for 2 h to let the fermentation process take place. After the first hour of incubation, dough was punched and placed in the incubator again. After completing fermentation process the dough was taken out to the oven to baking at 230°C/30 min. After baking, breads were left to cool at room temperature for about 1 h. and packed in Zip lock plastic bag under vacuum and stored at room temperature 22±2°C till further analysis.

Chemical Composition

Moisture, crude protein, crude fat and ash contents were estimated using AOAC (2012). Total (TDF), soluble (SDF), and insoluble (IDF) dietary fiber were determined by the enzymatic and gravimetric methods as described by (McCleary *et al.*, 2012). All analyses were performed in triplicates.

Functional Properties

Hydration properties in terms of water holding capacity (WHC), swelling capacity (SC) and water solubility index (WSI) were determined as described by (de Escalada Pla *et al.*, 2010). Colour was determined in terms of L* (indicates degree of lightness), a* (indicates degree of redness to greenness) and b* (indicates degree of yellowness to blueness), using the Hunter Lab ColourFlex EZ Spectrophotometer (AACC, 2000). The total colour difference was calculated from the following equation:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

ΔL^* , Δa^* , Δb^* are the differences between the L*, a* and b* values of experimental and control samples.

Rheological Characteristics

The farinograph (Brabender, Duisburg, Germany) was used to study the mixing profile of bread dough as function of the experimental factors (portion of AIR-PPB and its particle size). The following parameters were taken from the farinograms as described in the AACC (2000). Water absorption (WA., %), Dough development time (DDT., min), Dough stability (DS., min) and Dough weakening (DW., B.U).

Physical Properties of Bread

Loaves weights were recorded by 2-decimal digital balance. Bread volume was determined using rapseed displacement method (AACC, 2000). The specific volume of the bread was measured by bread loaf volume divided by loaf weight. Hardness of the breads were carried out after 1 h of baking using CT3 Food Texture Analyzer, wherein the pre-test rate was 1.0 mm/s, the side-center rate was 3.0 mm/s, the side-center rate was 3.0 mm/s, the trigger force was 5 g, the down-pressure variable was 50%, and the interval time was 5 s. Each sample was repeated 5 times.

Sensory Evaluation

Experimental breads were evaluated by carrying out hedonic test. After 1 h of baking, bread samples were cut into slices with a thickness of 1 cm and put in white foam plate and identified with random numbers. 32 untrained customers (12 male and 20 female, 21-30 years old) were invited to evaluate bread samples for quality attributes of: colour, taste, aroma, texture and overall acceptability, through 9 hedonic scale of liking or disliking (1: dislike extremely, 5: neither like nor dislike, 9: like extremely). To avoid sensory interferometry effect in evaluating samples, panelists were instructed to rinse mouth after evaluating each sample.

Experimental Design and Statistical Analysis

Response surface methodology was created by Statgraphics for Windows (version 4.1, Centurion XV, USA) for investigating the impact of incorporating AIR-PPB (2-15%) under different particle sizes (40-250 mesh) in wheat bread formulation and optimization for various responses. Ranges of the experimental factors were chosen after a set of preliminary experiments on mixtures trials, sensory acceptability was considered. Central composite rotatable DoE design was set with two numeric factors on two levels. Experimental design consists of randomized eleven runs with three replicates at the central point (Table 1). The design is to be run in a single block. One-way analysis of variance (ANOVA) and Duncan's multiple range test with significant differences ($P < 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of PPB

Table 2 shows the chemical composition of the AIR-PPB compared to the PPB. Results showed lower moisture content in the dry AIR-PPB (5.78 g/100g⁻¹) than the PPB (7.45 g/100g⁻¹). This is due to the higher bound water content of the PPB than AIR-PPB due to the presence of high protein content (14.65 g/100g⁻¹) as well as dietary fiber content. As regards protein content, a significant decrease ($P < 0.05$) was observed

Table 1. Experimental design

Trials	%	PS (mesh)
A1	(0), 9	(-α), 40
A2 (Central point, 3 replicate)	(0), 9	(0), 145
A3	(+1), 13	(+α), 250
A4	(0), 9	(+α), 250
A5	(-1), 4	(+1), 219
A6	(+α), 15	(0), 145
A7	(-1), 4	(-1), 70
A8	(+1), 13	(-1), 70
A9	(-α), 2	(0), 145
Control	0	0

Table 2. Proximate chemical composition of AIR-PPB and PPB

Composition*	AIR-PPB**	PPB***
Moisture	5.78±0.21	7.45±0.66
Protein	5.46±0.71	14.65±0.86
Fat	0.54±0.08	1.19±0.62
Ash	4.71±0.45	6.49±0.67
TDF	83.02±1.03	29.54±0.75
IDF	63.10±0.98	19.50±0.39
SDF	19.92±0.55	10.04±0.92
Soluble carbohydrates	6.28±0.43	48.13±1.94

* Dry weight basis

** Alcohol insoluble residue of potato peel by-product

*** Potato peel by-product

for AIR-PPB by 3 times lower than PPB. This indicates a high alcohol soluble protein fraction in PPB. It is worth noting that the protein content of AIR-PPB is greater than others by-product fiber concentrates such as banana peel (3.6 g/100g⁻¹) (Ajila *et al.*, 2008), pineapple (4.0 g/100g⁻¹) and guava (4.8 g/100g⁻¹) but lower than that of mango (8.0 g/100g⁻¹), (Martínez *et al.*, 2012), date pomace (10.7 g/100g⁻¹) and apple pomace (6.00 g/100g⁻¹) (Bchir *t al.*, 2014). Fat contents were low for either AIR-PPB or PPB (0.54 and 1.19 g/100g⁻¹, respectively). The fat

content of AIR-PPB is lower than of mango peel (2.5 g/100g⁻¹) (Ajila *et al.*, 2008), by-product fiber concentrates of passion fruit (0.8 g/100g⁻¹), pineapple (1.3 g/100g⁻¹) and guava (1.4 g/100g⁻¹) (Martínez *et al.*, 2012). The ash content in the AIR-PPB or PPB was 4.71 g/100g⁻¹ and 6.49 g/100g⁻¹. The ash content of the AIR-PPB revealed to be significantly higher ($P < 0.05$) than that of mango peel (3.4 g/100g⁻¹) (Ajila *et al.*, 2008), pineapple peel (3.18 g/100g⁻¹) (Wu and Shiau, 2015), pomegranate peel (2.7 g/100g⁻¹) (Ismail *et al.*, 2014), apple pomace (1.4

g/100g⁻¹), and date pomace (2 g/100g⁻¹) (Bchir *et al.*, 2014). Results also showed a significant increase ($P < 0.05$) in the TDF content of the AIR-PPB with about 3 times higher than PPB. This is due to the method of extraction used, where the use of alcohol leads to the removal of alcohol soluble components such as protein, sugars and minerals, which leads to an increase in the proportion of dietary fiber that does not soluble in alcohol. The recorded TDF of the AIR-PPB (83.02 g/100g⁻¹) was higher than in mango peel (51.20 g/100g⁻¹) (Ajila *et al.*, 2008), pomegranate peel (17.53 g/100g⁻¹) (Ismail *et al.*, 2014) citrus peels (57 g/100g⁻¹) (Chau and Huang, 2003), grape pomace skins (67.95 g/100g⁻¹) (Bender *et al.*, 2017). The TDF was similar to the contents found in apple pomace (82.00 g/100g⁻¹), and date pomace (83.70 g/100g⁻¹) (Bchir *et al.*, 2014) and passion fruit by-product fiber concentrates (81.50 g/100g⁻¹) (Martínez *et al.*, 2012). The results show that the part of the insoluble fiber fraction was prevalent in both the AIR-PPB and PPB (63.10 and 19.50 g/100g⁻¹) representing 76% and 66% of the TDF respectively. Soluble dietary fiber (SDF) had the value of 19.92 and 10.04 g/100g⁻¹ for AIR-PPB and PPB respectively. Similar trend was observed in pineapple peel (Wu and Shiau, 2015), apple pomace, date pomace (Bchir *et al.*, 2014) and orange by product (Ocen and Xu, 2013). The total available carbohydrate content (48.13 g/100g⁻¹) in the PPB was higher than that found in AIR-PPB (6.28 g/100g⁻¹). The total available carbohydrate content of AIR-PPB was higher than that of grape pomace skins (1.40

g/100g⁻¹) (Bender, Speroni *et al.*, 2017), but lower than that found in reported in citrus peel fiber (27.00 g/100g⁻¹), guava fiber (28.00 g/100g⁻¹) (Chau and Huang, 2003).

Functional Properties of AIR-PPB

Hydration properties consider important properties for fiber rich fractions physiologically and technologically. It is strongly related to the chemical structure of the polysaccharides as well as physical factors such as particle size, porosity, ionic form and strength, pH and temperature. To investigate the hydration properties of the AIR-PPB, water-holding capacity (WHC), swelling capacity (SWC) and water solubility index (WSI) were measured corresponding to a specific granules particle sizes range. The hydration properties of AIR-PPB are presented in Fig.1. Water-holding capacity is defined as the amount of water trapped by 1 g of dry fiber under specific conditions meanwhile swelling capacity defined as the volume occupied by a known weight of samples under the condition used. AIR-PPB was characterized by high hydration capacity in respect of its particle size, where, a reduction in the particle size of the AIR-PPB from 250µm to 40µm had been associated to decrease ability of fiber rich fraction to retain water. This is evidenced by the remarkable decrease in the WHC (from 7.75 to 6.73 mL/g) and SC (from 5.91 to 4.53 mL/g) corresponding to decrease in Particle sizes from 250µm to 40µm, respectively. Similar trend was observed for functional properties of unripe banana flour and

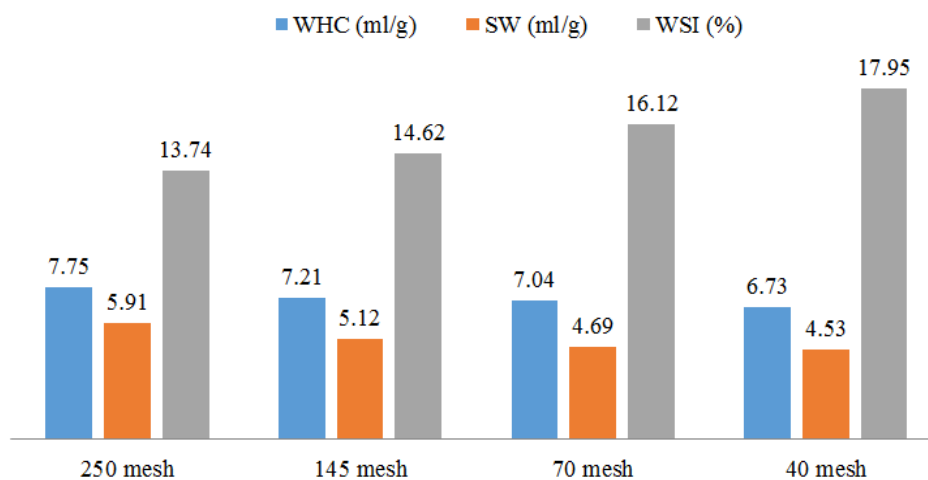


Fig. 1. Hydration properties of AIR-PPB corresponding to particle size

chestnut flour, wheat bran and coconut fiber responding to particle size (Raghavendra *et al.*, 2006; Ahmed *et al.*, 2016; Savlak *et al.*, 2016). On the contrary, WSI had negative and significant correlated to particle size of the AIR-PPB powder. Results showed a steadily increase in WSI (from 13.74 to 17.95%) with the decrease in particle size from 250 mesh to 40 mesh. This is due to a difference in the structural composition of the cell walls polysaccharides, regarding the small particle size, this fibrous structure breaks down leading to the release of soluble sugars, in contrast to the large particle size, where the fibrous structure maintain without demolition (Chau and Huang, 2003; Elleuch *et al.*, 2011).

Farinograph Characteristics

Rheology has an important role in cereal industry, especially in what concerns breadmaking (Ktenioudaki and Gallagher, 2012). As shown in Table 3, Fig. 3A the water absorption increased significantly ($P < 0.05$) with increasing in portion of AIR-PPB and particle size, the highest was found in dough with 13% AIR-PPB and particle size of 250 mesh being (74.18%) against the control dough (60.21%). This result can be explained by the fact of high dietary fiber content of AIR-PPB specially at high particle size, which had great number of hydroxyl groups which interact with water through hydrogen bonds (Bolek, 2020). This result is agreed with the previous findings of Rosell *et al.* (2001), Sudha *et al.* (2007), Liu *et al.* (2019) and Bolek (2020). Similar trend was observed for dough development time, wherein it increased at high AIR-PPB level and particle size (Table 3), Fig 3B. Thus, it increased from 1.40 min to 2.18 min during addition of 13% AIR-PPB and particle size of 250 mesh. It is due to the existence of AIR-PPB which impaired the gluten network resulting in slow water absorption and increase in time needed for dough to reach its optimal state (Tarek-Tilistyák *et al.*, 2014; Liu *et al.*, 2019). Results showed that incorporation of AIR-PPB reduced dough stability time in contrast to the particle size which increases the stability time at high size (Table 3), Fig. 3C. Thus, it decreased from 5.10 min (control) to 2.87 min during addition of 15% AIR-PPB and particle size of 145 mesh.

It is due to the role of AIR-PPB in dough matrix of blocking the hydration and extension of peptides which obstacle the formation and expansion of the gluten network through mixing process (Noort *et al.*, 2010; Liu *et al.*, 2019). It is clear that dough with low stability time had high dough weakening. Dough with lower weakening degree is preferred, while higher value indicates more difficulties during mechanical handling and makeup of the dough. Results showed an increase in dough wakening as incorporated AIR-PPB increased; on the contrary particle size had inverse impact on dough weakening (Table 3 and Fig.3D). The highest dough weakening degree was observed during addition of 15% AIR-PPB and particle size of 145 mesh (139.36) against the control (98). This is due to the impact of AIR-PPB in damaging the gluten matrix resulting in dough weakening.

Dietary Fiber Content and Quality Characteristics of Bread

Dietary fiber contents of breads are given in Table 4. Significant differences ($P < 0.05$) between experimental breads were observed compared to the control bread. It could be noticed that as the level of AIR-PPB increased at higher particle size in bread formulation, the TDF content of bread increased significantly ($P < 0.05$) (Fig. 3A). TDF content of experimental breads ranged from 7.91% for bread formulated with 2% AIR-PPB at particle size of 145 mesh, reaching the highest content (16.29%) for bread with 13% AIR-PPB at particle size of 250 mesh, higher by about 10 folds than the control (1.56). IDF was the dominant fraction of dietary fiber representing more than 70% of TDF for experimental breads comparing to 68% for control. IDF contents increased in parallel to increasing in portion of AIR-PPB and particle size. The highest IDF content was observed for bread formulated with 13% AIR-PPB at particle size of 250 mesh being 13.46% against the control (1.06). As regards SDF content, the particle size of AIR-PPB added had a negative correlation. The decrease in particle size is accompanied by the occurrence of cell wall IDF into soluble fiber fraction. Bread formulated with 15% AIR-PPB at particle size of 145 mesh had the highest SDF content (3.90%) against the control (0.50%).

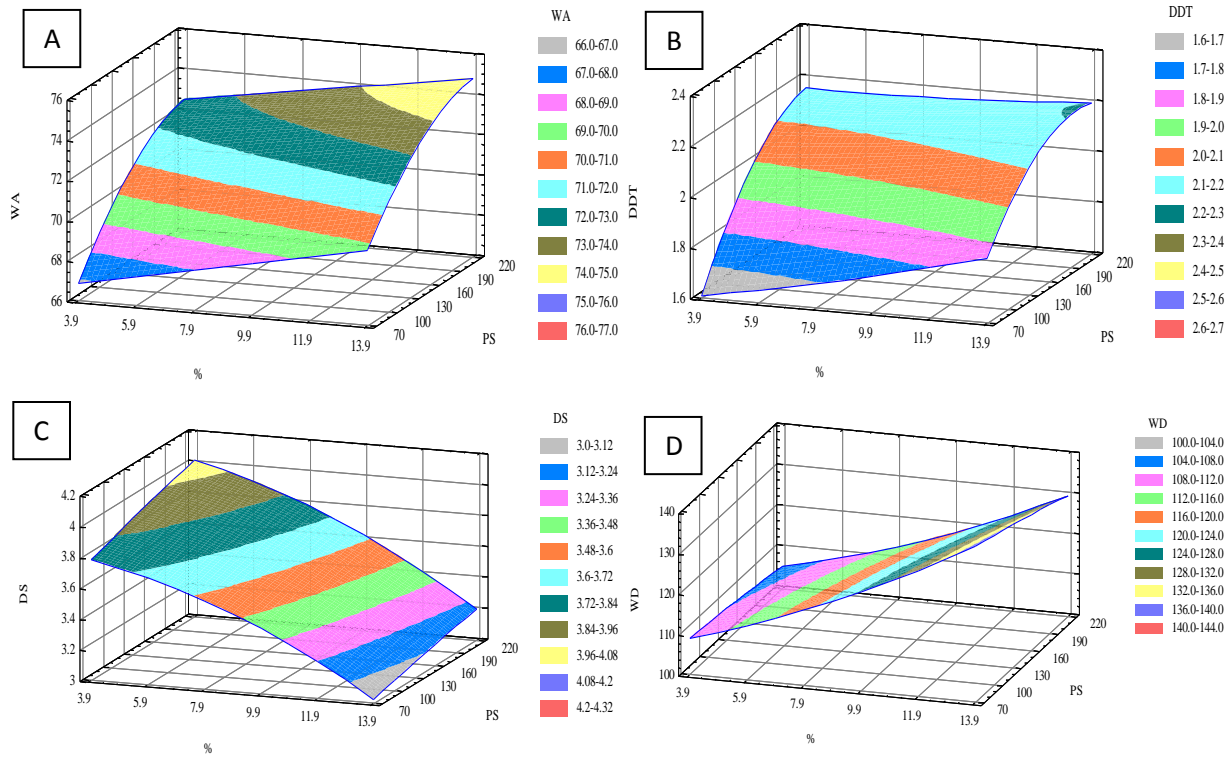


Fig. 2. Rheological properties of the experimental dough formulated with AIR-PPB

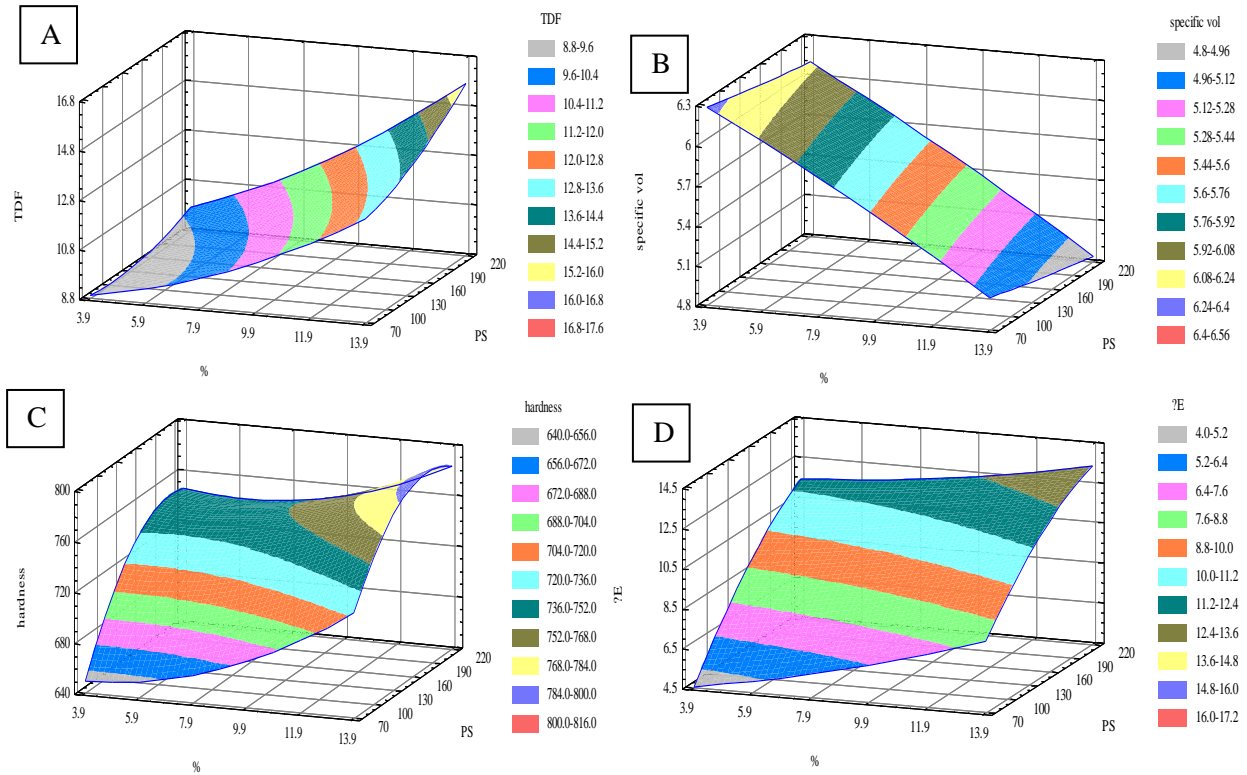


Fig. 3. Dietary fiber and quality characteristics of bread

Table 3. Rheological properties of the experimental dough formulated with AIR-PPB

Trials	Water absorption (%)	Dough development (min)	Stability time (min)	Weakening degree
A1	66.03±1.32 ⁱ	1.50±0.08 ⁱ	3.31±0.68 ^h	122.20±2.54 ^d
A2 (Central point, 3 replicate)	72.09±1.43 ^e	2.06±0.02 ^e	3.61±0.22 ^f	119.54±2.21 ^e
A3	74.18±1.70 ^b	2.18±0.01 ^a	3.37±0.18 ^g	125.66±2.21 ^c
A4	74.11±1.54 ^c	2.14±0.00 ^b	3.75±0.13 ^e	110.88±2.65 ^f
A5	72.89±1.50 ^d	2.13±0.51 ^c	4.02±0.19 ^b	107.19±2.98 ^g
A6	74.24±1.00 ^a	2.11±0.11 ^d	2.87±0.01 ^j	139.36±1.83 ^a
A7	67.42±1.30 ^h	1.59±0.03 ^h	3.83±0.01 ^d	110.88±1.93 ^f
A8	69.18±1.14 ^g	1.89±0.21 ^g	3.30±0.00 ⁱ	133.73±2.08 ^b
A9	69.87±1.28 ^f	2.02±0.00 ^f	3.97±0.72 ^c	101.77±0.00 ^h
Control	60.21±0.00 ^j	1.40±0.00 ^j	5.10±0.51 ^a	98.00±0.00 ⁱ

Table 4. Physicochemical properties of the experimental breads

Trials	TDF	IDF	SDF	Loaf weight (g)	Loaf volume (mL)	Specific volume	L	a	b	ΔE
A1	10.94±0.67 ^g	8.56±0.16 ^f	2.38±0.00 ^d	265.01±1.87 ⁱ	1,555.65±8.54 ^e	5.87±0.24 ^e	61.88±0.02 ^a	12.30±0.13 ^a	20.32±0.09 ^j	-
A2 (Central point, 3 replicate)	11.16±0.43 ^f	9.06±0.10 ^e	2.10±0.12 ^e	266.94±1.86 ^a	1,489.67±6.45 ^f	5.58±0.14 ^f	59.57±0.00 ^b	10.13±0.09 ^b	22.69±0.07 ⁱ	3.95±0.01 ⁱ
A3	16.29±0.11 ^a	13.46±0.00 ^a	2.83±0.09 ^c	266.31±1.35 ^f	1,316.36±2.76 ^j	4.94±0.58 ^g	53.51±0.09 ^f	8.81±0.00 ^f	24.11±0.12 ^e	9.83±0.05 ^e
A4	11.64±0.00 ^c	9.76±0.01 ^c	1.88±0.00 ^f	266.41±1.37 ^e	1,457.67±3.65 ^g	5.47±0.60 ^g	49.54±0.00 ^c	8.43±0.26 ^j	24.61±0.00 ^a	13.62±0.01 ^a
A5	11.22±0.21 ^e	9.75±0.03 ^d	1.47±0.00 ^h	266.43±1.48 ^d	1,612.76±6.88 ^d	6.05±0.08 ^d	50.04±0.51 ⁱ	8.47±0.31 ⁱ	24.56±0.20 ^b	13.14±0.01 ^b
A6	15.26±0.51 ^b	11.36±0.00 ^b	3.90±0.02 ^a	265.56±2.32 ^h	1,279.44±1.87 ^j	4.82±0.47 ^j	51.62±0.10 ^b	8.64±0.06 ^h	24.52±0.06 ^c	11.67±0.01 ^c
A7	9.05±0.11 ^h	7.53±0.12 ^h	1.52±0.31 ^g	266.94±1.89 ^a	1,640.66±9.83 ^c	6.15±0.52 ^c	51.76±0.00 ^g	8.71±0.26 ^g	24.23±0.19 ^d	11.43±0.05 ^d
A8	11.55±0.02 ^d	8.52±0.00 ^f	3.04±0.00 ^b	266.73±2.67 ^c	1,349.42±9.54 ^h	5.06±0.36 ^h	59.34±0.00 ^f	10.08±0.24 ^c	22.83±0.14 ^h	4.21±0.03 ^h
A9	7.91±0.27 ^j	6.64±0.04 ⁱ	1.27±0.01 ⁱ	266.88±1.12 ^b	1,730.45±7.54 ^b	6.48±0.13 ^b	54.84±0.05 ^d	9.48±0.18 ^d	23.65±0.11 ^g	8.28±0.09 ^g
Control	1.56±0.01 ^j	1.06±0.10 ^j	0.50±0.00 ^j	266.11±1.77 ^g	1,887.54±5.87 ^a	7.09±0.97 ^a	54.02±0.03 ^e	9.30±0.00 ^e	24.03±0.00 ^f	9.19±0.00 ^f

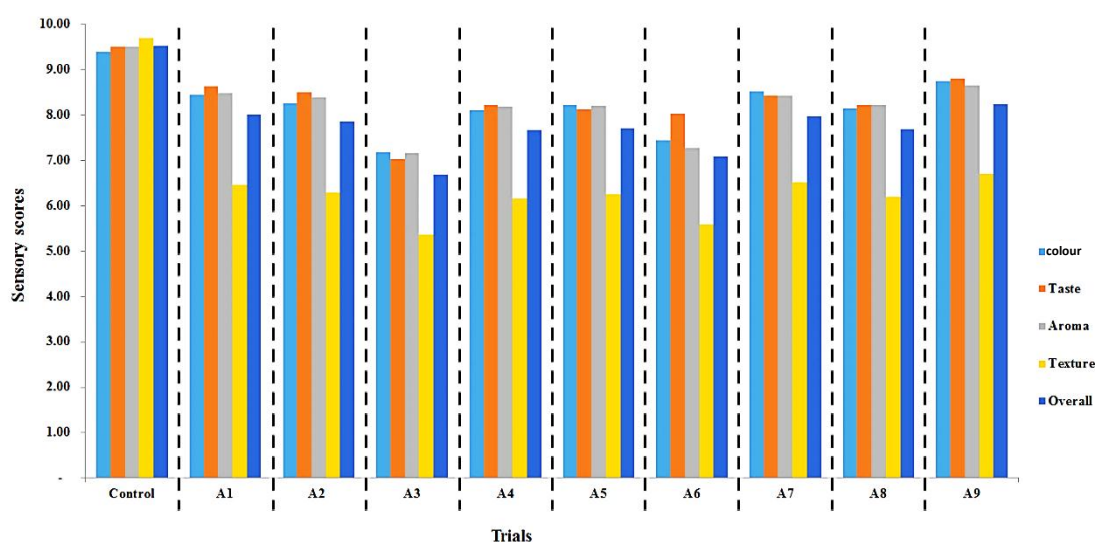


Fig. 4. Sensory evaluation of the experimental breads

The effects of AIR-PPB powder substitution at the experimental particle size on physical properties of breads are presented in Table 4. No significant differences in loaf weight corresponding to the experimental factors; the average weight of loaf weight was 266.42 g. A significant decrease ($P < 0.05$) in loaf volume was noted with an increase in the AIR-PPB powder level at higher particle size. The control loaf volume was 1887.54 ml, decreasing to 1279.44 ml for breads made with 15% AIR-PPB powder at particle size of 145 mesh. The absence of any effect of the experimental factors on the loaves weight in parallel with the decrease in the loaves volume, led to a decrease in the loaves specific volume (Fig. 3B). The reduction in volume and specific volume occurs by gluten dilution and changes in crumb structure, which in turns impairs carbon dioxide retention (Lim *et al.*, 2011; Mau *et al.*, 2020). These results are in agreement with those reported by Fendri *et al.* (2016) and Sęczyk *et al.* (2017).

Texture of breads was determined in terms of hardness property because of its relation with bread freshness and direct impact on customer acceptance. Regarding the effect of AIR-PPB and its particle size on texture, bread becomes harder as the portion of AIR-PPB increased at higher particle size (Fig. 3C). The bread hardness ranged between 612.93 g for formulation contained 9% AIR-PPB powder at particle size of 40 mesh and 813.17 g for formulation contained 15% AIR-PPB powder at particle size of 145 mesh, against the control 458.38 g. This impact is due to the increment of fiber content which creates hard compact structure because of its interaction with gluten and impairs gluten network optimal formation.

Colour is one of the most important quality parameters in food products. Undoubtedly, possible colour changes would influence the organoleptic properties of fortified breads. Table 4 shows the variation of L^* , a^* and b^* according to different portion of AIR-PPB at different particle sizes in the formulation of breads.

Table 4 showed the crust colour of the breads, analysed with L^* , a^* and b^* values. L^* measured the lightness of the breads, where the higher portion of AIR-PPB added and high particle size, darker the bread is. The darker

bread (49.54) was observed for bread contained 13% AIR-PPB powder at particle size of 250 mesh, meanwhile the lighter bread (59.57) was observed for bread contained 9% AIR-PPB powder at particle size of 40 mesh against the control (61.88). For the a^* , which measures the redness (+) to greenness (-). All breads tend to be red. The higher portion of AIR-PPB added and high particle size, the lower amount of bread redness was observed. The highest a value (1013) was observed for bread contained 9% AIR-PPB powder at particle size of 40 mesh compared to the control (12.30). b^* value represent the yellowness (+) to blueness (-). It could be noticed that as portion of AIR-PPB and its particle size increased, the more amount of yellowness of breads were observed. The highest b value (24.61) was obtained for bread contained 13% AIR-PPB powder at particle size of 250 mesh compared to the control (20.32). Regarding the changes in colour ΔE , the experimental breads show drastic colour changes due to having a relatively high amount of AIR-PPB and high particle size. The highest colour change (13.62) was observed for bread contained 13% AIR-PPB powder at particle size of 250 mesh, meanwhile the lowest colour change (3.95) was observed for bread contained 9% AIR-PPB powder at particle size of 40 mesh (Fig. 3D).

Sensory Evaluation

It was shown that AIR-PPB addition and its particle size had an inverse significant effect ($P < 0.05$) on all of the bread sensory properties. All the sensory attributes evaluated (colour, taste, aroma, texture and overall acceptability) of the experimental breads samples scored more than six points, meaning that these samples were acceptable.

Referring the attributes of colour, taste and aroma of bread samples, results showed consumer high preference score (higher than 7) comparing to control bread. The highest scores of colour, taste and aroma were 8.75, 8.80 and 8.66, respectively for bread contained 2% AIR-PPB powder at particle size of 145 mesh was close to control. It was noted that the texture scores were the lowest among the measured sensory characteristics. This is because with the increase in the portion of AIR-PPB added as well as its particle size, the degree of hardness and

compactness of breads crumbs increase, which is not desirable to consumers. In terms of texture, results showed that bread contained 2% AIR-PPB powder at particle size of 145 mesh had the most acceptable rate (6.71), meanwhile bread contained 13% AIR-PPB powder at particle size of 250 mesh was not acceptable (5.37). According the sensory evaluation, the conditions of the most acceptable samples which could be recommended were as follows: bread contained 2% AIR-PPB powder at particle size of 145 mesh (8.23); bread contained 9% AIR-PPB powder at particle size of 40 mesh (8.01); bread contained 4% AIR-PPB powder at particle size of 70 mesh (7.98).

Conclusion

In this investigation, alcohol insoluble residue from potato processing by-product blended wheat bread was evaluated for rheological, chemical and functional properties as affected by different addition portions levels of AIR-PPB at different particle sizes in bread and optimized using response surface methodology. Results showed positive effects for experimental breads associated with the increment of total dietary fiber content as well as the consumers' acceptance of the sensory properties of the experimental breads at all levels of addition and particle sizes in the experimental ranges. On the other hand, there are some adverse effects that are related to the dilution of the gluten network, which reflected on the dough stability and weakness. In addition, decrease in breads specific volume and decrease in crumb hardness were observed. Finally, bread contained 2% AIR-PPB powder at particle size of 145 mesh; bread contained 9% AIR-PPB powder at particle size of 40 mesh and bread contained 4% AIR-PPB powder at particle size of 70 mesh are recommended and can be successfully used at industrial scale.

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التأثيرات الريولوجية والكيميائية والوظيفية للخبز المدعم بالمتبقيات غير الذائبة في الكحول من مخلفات تصنيع البطاطس باستخدام منهجية استجابته السطح

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تهدف هذه الدراسة الى تقييم وتحديد الظروف المثلى لاضافه البقايا غير الذائبة في الكحول المحضرة من مخلفات تصنيع البطاطس (AIR-PPB) الى دقيق خبز القمح عند مستويات مختلفه من حجم الجزيئات باستخدام منهجية استجابته السطح. أظهرت النتائج تحسنا في الخواص الوظيفية للبقايا غير الذائبة في الكحول المحضرة من مخلفات تصنيع البطاطس من حيث قدرتها على ربط الماء وسعه الانتفاخ ومؤشر الذوبانية المائي بزياده حجم الجزيئات. كما أظهرت النتائج الارتباط بين ارتفاع نسبه AIR-PPB المضافه ذات حجم الجزيئات الكبيره مع ارتفاع محتوى الألياف الغذائية الكلية ، امتصاص الماء (WA) ، وقت تطور العجين (DDT). تعطى الجزيئات ذات الحجم الكبير المزيد من الاستقرار في التركيب الهيكلي للعجين ولكن كان لارتفاع حجم الجزيئات تأثيرا عكسيا على درجه إضعاف العجين (DW). ولقد ارتبطت أنخفاض الحجم النوعي للخبز وزيادة درجة صلابته مع الارتفاع في نسبه AIR-PPB المضافه و ارتفاع حجم جزيئاتها. وقد أظهر التقييم الحسى قبول المستهلكين للخبز التجريبي الى جانب العينه القياسيه.

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