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IMPACT OF FIBER-RICH FRACTION OF BANANA PEELS AS DIETARY FIBER SOURCE FOR PRODUCTION OF FIBER-ENRICHED COOKIES

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ABSTRACT: Interest in dietary fiber as a functional ingredient is steadily increasing especially those that come from manufacturing waste. The present study aimed to investigate the effects of the addition of alcohol-insoluble fraction from banana peels (AIF-BP) at different particle sizes (PS)on cookies. AIF-BP was characterized by higher content of dietary fiber as well as its Water holding capacity (WHC) and Oil holding capacity (OHC) in respect of its PS. As portion of AIF-BP and PS increased farinograph parameters of water absorption (WA), dough development time (DDT) and dough weakening (DW) increased but had inverse effect on dough stability (DST). Fiber-enriched cookies (FEC) with lower spread ration and higher hardness were companied with the increment in AIF-BP at higher PS. All the sensory attributes of experimental and control FEC were acceptable.

Key words: Banana peel, *Musa* sp., alcohol insoluble fraction, dietary fiber, cookies, functional properties.

INTRODUCTION

Banana (*Musa* sp.) is tropical fruit has an increasing consumption due to its pleasant taste, flavor, texture, and its contents of nutrients **(Vu *et al*., 2019)**. Bananas are also the world's first traded fresh fruit **(Rosmiza *et al*. 2016)**.The average worldwide banana yield was estimated to be 115 million tones**.** The high consumption of bananas, whether fresh or post-processing, generates a large amount of waste; accounting for 40% of the total weight of fresh fruit **(Odedina *et al*., 2017)**. The use of these wastes in food composites added value to the production chain, as well as overcoming the environmental problems associated with this waste accumulation.

Besides its contents of protein (6-9%), fat (3.8-11%) and many other minerals and free sugars **(Mohapatra *et al*. 2010),** literatures have shown that banana peels are rich in polyunsaturated fatty acids such as linoleic acid (Omega-6) and α-linolenic acid (Omega-3), which account for more than 40% of the total fatty acids. Also, Banana peel can be considered as a good source of essential amino acids **(Tsado *et al*., 2021).** With a TDF content of (43.2–49.7%), banana peel is considered rich source of dietary fiber consists of pectin (10-20%), hemicellulose (17-40%), cellulose (18-60%), xylose (12%) and lignin (16-31%) which can be converted into to higher value-added oligosaccharides **(Oliveira *et al*., 2016; Odedina *et al*., 2017; Harini *et al*., 2018; Pereira *et al*., 2021)**. Therefore, it is possible to recycle banana peels into beneficial functional components, such as prebiotic dietary fiber. It is a cheap source of dietary fiber. Literatures have illustrated many of the health benefits associated with increased consumption of high-fiber foods, including a reduced risk of coronary heart disease because they alter blood lipid profiles, lower blood pressure and reduce glucose concentrations. in addition, reduced risk of obesity, diabetes and some kinds of cancer **(Lan *et al*., 2012; Wu *et al*., 2015)**.

Dietary fiber is considered as a functional ingredient with promising technological properties such as increase water and oil binding capacity. Besides its ability to modify textural properties and avoid Syneresis (the separation of liquid

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from a gel caused by contraction), stabilize high fat food and emulsions, and improve shelf-life **(Elleuch *et al*., 2011)**.

In order to enhance the functions of DF and produce fiber-enriched products with properties close to the original product, studies have focused on two strategies: (1) the modification of dietary fiber by chemical, physical, enzymatic and fermentation methods prior to use **(Šoronja-Simović *et al.*, 2016; Ullah *et al*., 2017; Wen *et al*., 2017; Yu *et al*., 2018; Yoshida and Prudencio, 2020)** (2) controlling the percentage of added dietary fiber and its PS **(Elleuch *et al*., 2011)**

Banana peels have been currently applied in several food products for improving nutritional and physicochemical properties. In bread and bakery productions, banana peels have been used to replace (1–30%). The initial improvement in nutritional compositions, free radical scavenging activity, phytochemical content, and antioxidant activity could be observed with 5% of banana peel replacement in food formulas **(Eshak 2016)**. The substitution of banana peel at 10% showed significant improvement the rheology and texture properties such as hardness, springiness, and chewiness of the products with good acceptability **(Gomes *et al*., 2022)**. Banana peel substitution at levels of 20% could initiate poor physical and sensorial properties in gluten-free cakes and waffle cones products **(Zanariah *et al*., 2019)**. The lowest level of banana peel and pulp substitution (6.5%) found to be effective to increase dietary fiber content and control starch hydrolysis **(Ramli *et al*., 2009)**. The highest level of banana peel and pulp substitution in noodle/pasta formula that provided higher nutritional properties with the best sensory acceptability was at 15% **(Castelo-Branco *et al*., 2017).**

The objective of the present work was to study the application of alcohol-insoluble fraction from banana peels (AIF-BP) powder at different PSs in fiber-enriched cookies, evaluating their rheological, chemical, physical and sensory properties by using Response surface methodology.

MATERIALS AND METHODS

Raw Material

Fresh banana peels (*Musa* sp.) which represented 43% the total weight of banana fruit were obtained after washing the fruit with chlorinated water (50 ppm) in the juice production unit of the Faculty of Food Science, Faculty of Agriculture, Zagazig University, Egypt. After manual peeling, the obtained peels were collected and dried in an oven at 45 ± 2°C for 72 h. Dry banana peel (BP) was ground and sieved through 200, 176, 118, 59 and 35 µm sieves. The sifted powder is packed in a resealable plastic bag and stored at 10°± 2°C for approximately 1 hour until use.

Separation of the Alcohol-Insoluble Fraction from Banana Peels (AIF-BP)

Alcohol-insoluble fractions were separated from banana peels according to the method described by **Namir *et al*., (2015)** with slight modifications. Banana peel powder of each PS (100 g) was initially homogenized in 300 ml of boiling aqueous ethanol (70 % v/v) for 30 min using a blender (moulinex Moulinex LM2421EG). The suspension was then subjected to a centrifugation at 2500 rpm for 5 min and the supernatant was discarded. After collecting the residue this previous step was repeated until the filtrate was clear. The residue was then washed with 95% ethanol, washed with acetone and dried overnight with solvent exchange at room temperature. The AIF packaged in a self-sealing plastic bag and stored at 10°± 2°C until further analysis.

Experimental Design

The RSM with central composite design (CCD) of 5 coded levels, 2 independent variables, and 11 experimental runs including three center points (Table 4) was used to optimize the formulation of fiber enriched cookies including AIF-BP (X1, 3-20%) and its PSs (X2, 40-300 µm) using Statgraphics Plus for Windows (version. 1 Centurion XV, USA). The experimental design is shown in Table 1.

Using MS Excel 2010, Means and standard deviations of parameters were calculated. One-way ANOVA, followed by the Dunken's test were applied to compare the means that showed significant variation ($p < 0.05$)

To investigate the correlations between experimental variables and responses, a correlation matrix was carried out using software of MS Excel 2010.

Cookies Manufacturing Process

Cookies were prepared according to the methods of **(Stoffel *et al*., 2021)** with some modifications. The cookies basic ingredients were as follows: wheat flour (100 g, 13% moisture content), margarine (60 g), refined sugar (60 g), skimmed milk powder (5 g), whole egg (48 g), vanilla (2.5 g), sodium bicarbonate ($NaHCO_3$) (0.7 g) and ammonia salt (1 g). In the experimental fiber enriched cookies, wheat flour is substituted at different levels by AIF-BP at specific PSs, according to the experimental model. Cookie dough was prepared for each run in stationery spiral dough mixer (Black & Decker 1000W, USA). Margarine and eggs are mixed at speed 3 for 4 min until homogeneous mixture. Skimmed milk powder, refined sugar, vanilla, sodium bicarbonate (NaHCO3) and ammonia salt were mixed well and added to the mixture and mixed continuously at speed 2 until dissolving all of the visible particles, finally wheat flour was added and mixed at speed 2 for 5 min to form cohesive dough. The dough was rested for 30 min then kneaded and sheeted to a adjusted thickness of 10 mm and It was cut manually using stainless steel molds in a circular shape (40 mm of diameter). Baking was carried out in an Electric Oven at 180°C for 15 min and then cooled at room temperature (22±1°C) for two hrs and packed in Self-seal polyethylene bag till further analysis.

Rheological Characteristics

The farinograph (Brabender, Duisburg, Germany) was used to study the mixing profile of FEC dough as function of the experimental factors (portion of AIF-BP and its PS). 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).

Proximate Composition and Energy Value

The moisture, protein, fat and ash contents were determined according to the methods proposed by the Association of Official Analytical Chemists **(AOAC, 2016)**. Total dietary fiber (TDF). TDF was analyzed in terms of soluble (SDF) and insoluble dietary fiber (IDF) by enzymatic and gravimetric methods, described by **McCleary *et al.* (2012)**. An available carbohydrate was obtained by the difference as follows:

AC (g/100g) = 100-(moisture + ash + fat + protein + TDF)

The caloric value was calculated using the Atwater coefficients using the coefficient of calorie of 3.87 k.Cal for carbohydrate, 4.02 kcal for protein, and 9.0 kcal for fat, according to the following equation

Caloric value (kcal/100g)= (protein content × 4.02)+(Carbohydrates content × 3.87)+(Fat × 9)

Physical and Technological Properties

Water and oil holding capacity (WHC) and swelling capacity (SC) were determined according to methods described by **Namir *et al*. (2022).** Baking loss is measured as the difference between the weight of the dough before and after baking (loss upon baking). Diameter and thickness were measured by digital caliber) in mm) After 2 hrs of baking and the spread ratio (D/T) was estimated according to **AACCI (2010).** Color measurement in terms of $L*$, $a*$and $b*$ was determined by the Hunter Lab ColorFlex EZ (Hunter Lab., Virginia, USA).

The color change (ΔE) was calculated for each formulation according to the following equation:

$$\Delta E = \sqrt{(L_t - L_c)^2 + (a_t - a_c)^2 + (b_t - b_c)^2}$$

where L*, a* and b* are the brightness, redness and yellowness of control (c) and experimental trial (t) biscuits.

All measurements were carried out in triplicates. The cookies texture profile in terms of breaking strength value was measured by a texture analyzer (TA-XT plus, SMS, UK) according to the method described by (AACCI, 2010) (Probe of knife blade, load cell: 5 kg, pre-test: 1.5 $mm.s^{-1}$, test: 1.0 $mm.s^{-1}$, post-test speed: 5.0 $mm.s^{-1}$ and distance: 20 mm. the maximum force (N) required to cut the cookies was recorded. The cookies (24 h after baking)

Sensory Evaluation

To obtain an integrated perception of the success of the product in the market, the sensory evaluation was studied through acceptability test which including A nine-point hedonic scale ranging from 1 = Dislike extremely and 9 = Like extremely to evaluate the properties of appearance, color, aroma, taste, crispness and overall acceptability. Cookie samples were presented in white foam plates, randomly coded, in separate cabinets with fluorescent lighting, provided by a cup of water to be used by panelists to rinse mouth after evaluation for each sample to avoid overlap between samples. 42 non-trained panelists of food science department, faculty of agriculture, Zagazig University who are not allergic to any of the ingredients included in the cookies were invited to carry out the sensory analysis.

RESULTS AND DISCUSSION

Proximate Composition of AIF-BP

Regarding to the comparative chemical composition of the AIF-BP at the experimental PS as well as wheat flour, a significant decrease in the protein and fat contents of AIF-BP (4.12-4.59 $g/100g^{-1}$) and (2.11-2.18 $g/100g^{-1}$) can be observed compared to the wheat flour (10.26 g/ 100 g^{-1}) and (2.57 $g/100g^{-1}$) (Table 2). While there were no significant differences between protein and fat contents of AIF-BP at the experimental PS. It worth monitoring that wheat Flour is characterized by the presence of gluten, which plays an important role in the growth and development of the dough and gives the product the desired texture, unlike AIF-BP protein, which does not contain this type of protein. Protein content of the AIF-BP (4.12- 4.59 g/ $100g^{-1}$) is higher than that of mango peel (1.56 $g/100g^{-1}$) **(Noor Aziah *et al*., 2011)**, and orange peel by-product (0.43 $g/100g^{-1}$) **(Ocen and Xu, 2013)** but lower than that of cantaloupe by-product (15.22 $g/100g^{-1}$) **(Namir *et al*., 2021).** Fat content of the **AIF-BP** (2.11-2.18 $g/100g^{-1}$) is higher than that of pomegranate peel (0.4 $g/100g^{-1}$) **(Ismail *et al*., 2014)** and potato peel by-product (0.42-0.54 $g/100g^{-1}$) **(Namir *et al*., 2022)** but lower than that of tomato processing by-product (15.83 $g/100g^{-1}$) **(Namir *et al*., 2015)** and cantaloupe by-product (9.65 $g/100g^{-1}$) **(Namir *et al*., 2021)**.

In contrast, results showed a significant increase in the ash content for the AIF-BP at the experimental PS comparing to wheat flour (Table 2). While there were no significant differences between the experimental PSs of AIF-BP Ash content of the AIF-BP (6.04-6.51 $g/100g^{-1}$) is higher than that of mango peel (2.5 $g/100g^{-1}$) **(Noor Aziah *et al*., 2011)**, Pinapple peel (3.18 $g/100g^{-1}$) **(Wu *et al*., 2015)**, pomegranate peel (2.7 $g/100g^{-1}$) **(Ismail *et al*., 2014)**, and tomato processing by-product (3.10 $g/100g^{-1}$) **(Namir *et al*., 2015)** but lower than that of cantaloupe by-product (7.33 $g/100g^{-1}$) **(Namir *et al*., 2021)**.

The extraction method used to prepare AIF-BP as well as PS reduction showed notable differences in chemical composition, especially in terms of TDF content (Table 2). Total dietary fiber content accounted for the majority of the matrix (77.24-79.62%) compared to wheat flour (2.31%). This content is higher than that of some other DF preparation from cantaloupe peel (57.72%), guava peel (51.52%) and carrot peel (28.80%). This total dietary fiber content of more than 70 $g/100g^{-1}$ presents AIF-BP with a source of dietary fiber in food applications requiring high dietary fiber content with low energy. It is noted that with the decrease in PS from 300 to 40 µm, the total dietary fiber content decreased from 79.62 to 77.24 $g/100g^{-1}$, respectively (Table 2). This is because grinding and PS reduction causes a redistribution of the components of the IDF, which is the dominant fraction of the TDF. As the PS decreased, the hemicellulose content increased, but conversely, the cellulose, lignin and pectin content decreased. This is due to the effect of the PS reduction that causes the elimination of intermolecular chemical bonds between hemicellulose and lignin, in addition to the breakdown and solubilization of cellulose, lignin and pectin particles into small particles of small molecular weight, causing redistribution of polysaccharide components from insoluble to soluble form.

This is confirmed by the results given in Table 2 where the IDF decreased from 55.78 to 47.24 $g/100g^{-1}$, with the PS reduced from 300 to 40 µm. on the other hand**,** the soluble fraction increased from 23.84 to 30.00 $g/100g^{-1}$ as the PS decreased from 300 to 40 µm.

As a result of the high content of total dietary fibers, with a decrease in the content of fat, protein and soluble carbohydrates of AIF-BP,

Table 1. Experimental design

Block	X1, (g/100g wheat flour)	X2 (µm)
A1 (Central point, 3 replicate)	12	170
A2	18	78
A3	3	170
A4	18	262
A5	6	262
A6	12	300
A7	6	78
A8	12	40
A9	20	170
Control	0	0

Table 2. Proximate chemical composition and function properties of AIF-BP and wheat flour

Parameters ($g/100g^{-1}$)	wheat flour	PS (µm)				
		40	78	170	262	300
Moisture	11.19^{a}	8.32^{f}	8.48^{e}	8.69^{d}	8.88^{c}	8.96^{b}
Protein%	10.26^{a}	4.32^{e}	4.12^{f}	4.34^{d}	4.61^{b}	4.51^{c}
Fat%	1.57^{f}	2.13^{d}	2.14^{c}	2.05^{e}	2.18^{a}	2.16^{b}
Ash%	0.53^{f}	6.43^{b}	6.04^{e}	6.12^{d}	6.36^{c}	6.91^{a}
Soluble carbohydrates	85.33^{a}	9.88^{b}	9.14^{c}	8.37^{d}	7.39^{e}	6.80^{f}
TDF	2.31^{f}	77.24^{e}	78.56^{d}	79.12^{c}	79.46^{b}	79.62^{a}
IDF	1.34^{f}	47.24^{e}	52.17^{d}	53.37^{b}	55.34^{c}	55.78^{a}
SDF	0.97^{f}	30.00^{a}	26.39^{b}	25.75^{c}	24.12^{d}	23.84^{e}
Energy value (kcal/100 g)	385.65^{a}	74.77^{b}	71.19^{c}	68.29^{d}	66.75^{e}	63.89^{f}
WHC	2.07^{f}	5.69^{e}	5.71^{d}	5.73^{c}	5.85^{b}	5.91^{a}
OHC	1.34^{f}	1.50^{e}	1.53^{d}	1.71^{c}	1.74^{b}	1.82^{a}
L	93.14^{a}	58.73^{b}	55.98^{c}	50.04^{d}	46.5^{e}	45.18^{f}
a	(1.56)^{f}	6.21^{e}	7.26^{d}	7.44^{c}	8.31^{b}	9.45^{a}
b	9.13^{f}	52.22^{a}	48.94^{b}	44.17^{c}	40.81^{d}	38.14^{e}

this leads to a reduction in the energy generated, which ranged between 65.55 and 76.15 (kcal/ 100 g^{-1}) in respect of PS. The lowest energy produced from the AIF-BP was recorded at PS of 300 µm (65.55 kcal/100 g^{-1}), compared to wheat flour (390.76 kcal/100 g^{-1}) (Table 2).

Ingestion of IDF causes satiety because it absorbs water and increases the bolus size. It also increases the volume and weight of faecal bolus, promotes better functioning of the digestive system and prevents disorders such as constipation **(Viuda-Martos *et al*., 2012).**

The physicochemical properties of AIF-BP and wheat flour are shown in Table 2. The difference in AIF-BP physicochemical properties of WHC and OHC depends on the ratio of IDF/SDF, PS, extraction processes, presence of functional groups such as hydrophilic nature, surface area and structural features. Results showed that AIF-BP exhibiting higher WHC (5.69-5.91 ml/gm), than that of wheat flour to 2.07. Also, higher than that of pomegranate bagasse (4.50 ml/gm) **(Viuda-Martos *et al*., 2012),** grape pomace (2.17 ml/gm) **(Khodaei *et al*., 2020)** and tomato pomace (4.12 ml/gm) **(Namir *et al*., 2015)**.

Also, AIF-BP characterized by low OHC at the experimental PSs, which were significantly decreased with the decrease in PS, but generally, the values of OHC to AIF-BP exhibiting 1.50-1.82 ml/g were greater than that of in wheat flour (1.34 ml/g). The OHC value was higher than that of amaranth flour (1.04 ml/gm) **(Heleno *et al*., 2015)** close to that obtained for grape pomace (1.42 ml/gm) **(Khodaei *et al*., 2020)**, but it was lower than that of tomato pomace (2.92 ml/gm) **(Namir *et al*., 2015)**, and pomegranate (5.9 ml/gm) **(Ismail *et al*., 2014)** cantaloupe pomace (4.01 ml/gm) **(Namir *et al*., 2021).** Color represents one of the obstacles to the use of dietary fibers in food applications, because their color is different from the color of the mixture in which they are incorporated. Many chemical and physical factors affect fiber enriched fraction color by effecting the concentration, type and properties of pigments, which are related to the structure integrity of dietary fiber. In this study, two factors influenced the color of the DF: chemical (solvent extraction) and physical (crushing and sieving). A marked increase in the values of L and b and a decrease in the value of a is observed as the PS decreases. However, AIF-BP is characterized by dark brown to light brown in color with decreasing PS. This makes it suitable for use as an ingredient in many food applications especially in bakery products where the brown color has an advantage in enhancing the sensory quality of the product.

Farinograph Characteristics of Fiber-Enriched Cookies Composites

Rheology has an important role in cereal industry, especially in what concerns breadmaking **(Ktenioudaki and Gallagher 2012)**. As shown in Table 3, Fig 1A the water absorption increased significantly with increasing in portion of AIF-BP and PS, the highest was found in dough with 20% AIF-BP and PS of 170 µm being (67.78%) against the control dough (58.45%). This result can be explained by the fact of high dietary fiber content of AIF-BP specially at high PS, which had great number of hydroxyl groups which interact with water through hydrogen bonds **(Bolek, 2020).** This result is agreed with the findings of **(Rosell *et al*., 2001; Sudha *et al*., 2007; Liu *et al*., 2019; Bolek, 2020).** Similar trend was observed for dough development time, wherein it increased at high AIF-BP level and PS (Table 3), Fig 1B. Thus, it increased from 1.00 min to 4.00 min during addition of 20% AIF-BP and PS of 170 µm. It was due to the existence of AIF-BP which impaired the gluten network resulting in slow water absorption and increase in time needed for dough to reach its optimal stat **(Tarek-Tilistyák *et al*., 2014; Liu *et al*., 2019).** Results showed that incorporation of AIF-BP reduced dough stability time in contrast to the PS which increases the stability time at high size (Table 3 and Fig. 1C). Thus, it decreased from 10.50 min (control) to 2.00 min during addition of 20% AIF-BP and PS of 170 µm. it is due to the role of AIF-BP 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

Table 3. Rheological properties of the experimental FEC dough formulated with AIF-BP

BLOCK	Water absorption (%)	Dough development (min)	Dough stability time (min)	Dough weakening degree (B.U)
A1 (Central point, 3 replicate)	65.36[e]	2[e]	4.5[f]	80[e]
A2	66.14[c]	3[c]	3[h]	70[g]
A3	63.22[h]	2[e]	7[b]	115[a]
A4	66.88[b]	3.5[b]	2.5[i]	60[h]
A5	64.58[f]	2[e]	6[d]	95[c]
A6	65.83[d]	2.5[d]	4[g]	75[f]
A7	63.37[i]	2[e]	6.5[c]	100[b]
A8	65.16[g]	2[e]	5.5[e]	90[d]
A9	67.78[a]	4[a]	2[j]	60[h]
Control	58.45[j]	1[f]	10.5[a]	50[i]

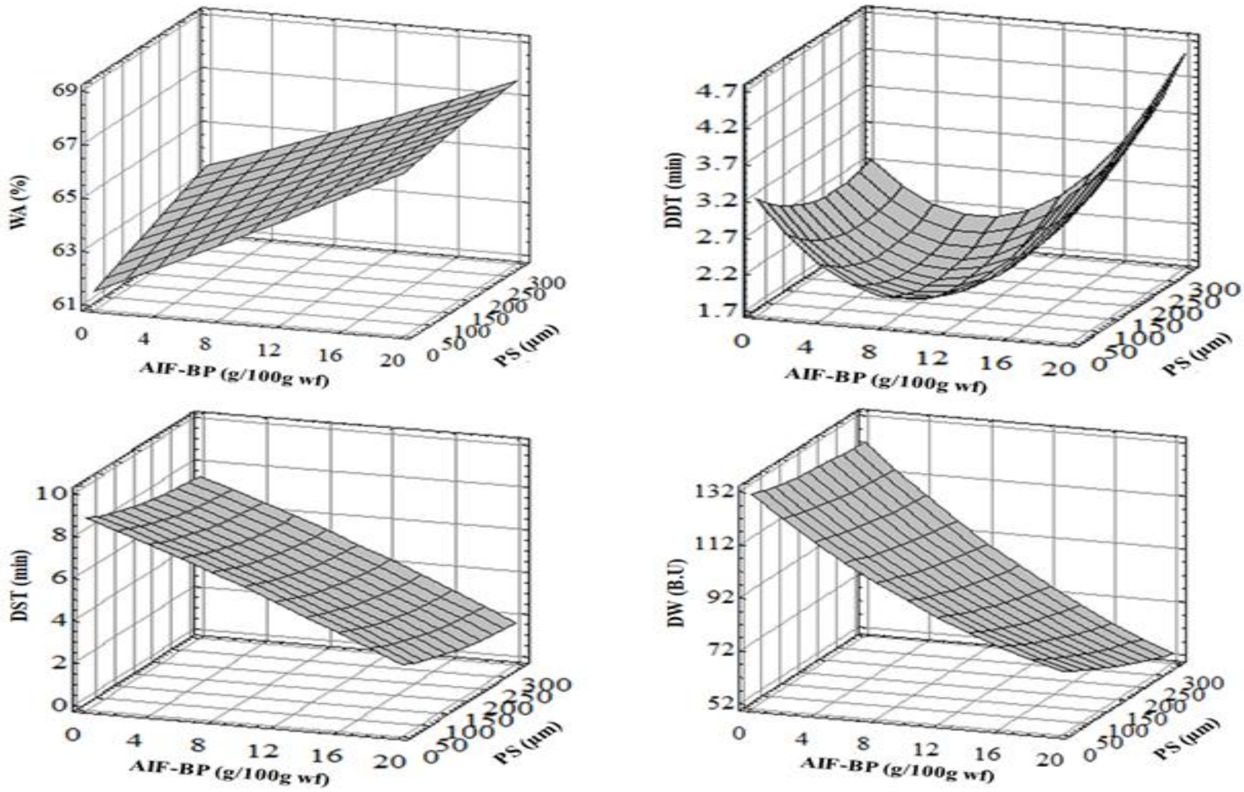

Fig. 1. Rheological properties of the experimental dough formulated with AIF-BP

difficulties during mechanical handling and makeup of the dough. Results showed an increase in dough wakening as incorporated AIF-BP increased; on the contrary PS had inverse impact on dough weakening (Table 3), Fig. 1D. The highest dough weakening degree was observed during addition of 3% AIF-BP and PS of 170 µ (115.00 B.U) against the control (50.00 B.U). This is due to the impact of AIF-BP in damaging the gluten matrix resulting in dough weakening.

Dietary Fiber Content and Quality Characteristics of Fiber-Enriched Cookies (FEC)

Dietary fiber contents of FEC are given in (Table 4). Significant differences between experimental cookies were observed compared to the control. It could be noticed that as the level of AIF-BP increased at higher PS in FEC formulation, the TDF content of bread increased significantly. TDF content of experimental ranged from 4.61% for bread formulated with 3% AIF-BP at PS of 170 µm, reaching the highest content (17.67%) for FEC with 20% AIF-BP at PS of 170 µm, higher by about 8 folds than the control (2.31%).

IDF was the dominant fraction of dietary fiber representing more than 61-68% of TDF for experimental FEC comparing to 58% for control. IDF contents increased in parallel to increasing in portion of AIF-BP and PS. The highest IDF content was observed for FEC formulated with 20% AIF-BP at PS of 170 µm being 11.75% against the control (1.34). As regard for SDF content, the PS of AIF-BP added had a negative correlation. The decrease in PS is accompanied by the occurrence of cell wall IDF into soluble fiber fraction. FEC formulated with 20% AIF-BP at PS of 170 µm had the highest SDF content (5.92%) against the control (0.97%)

The physical characteristics of wheat and composite FEC are shown in Table 4. Wheat cookies showed weight (4.11 g), diameter (51.10 mm), thickness (6.12 mm), spread ratio (8.35), baking loss (13.45%) and hardness (1164.23 g). However, the addition of AIF-BP at higher PS in FEC significantly ($p<0.05$) increased the weight, thickness and hardness, but decreased diameter, spread ratio and baking loss (Table 5).

An increase in weight with AIF-BP addition with high PS which ranged from 5.53 g to 6.13 g the highest value (6.13g) was obtained for FEC formulated with 20% AIF-BP at PS of 170 µm comparing to the control (4.11g) This parameter provides information on the level of the weight loss during baking and correlates with the baking yield **(de Toledo *et al*., 2017).**

An increase in thickness which varied from 6.95 mm to 7.78 mm comparing to the control (6.12 mm) could be attributed to the increased water absorption capacity of fiber components, which affected gluten dough network and consistency. A previous report of increasing thickness of wheat cookies supplemented with orange pomace has been reported (Larrea, Chang et al. 2005). However, decrease in cookies diameter from 40.72 mm to 47.35 mm and spread ratio from 5.23 to 6.82 by increasing in AIF-BP addition and its PS. The highest diameter (47.35 mm) and spread ratio (6.82) were observed in FEC formulated with 3% AIF-BP at PS of 170 µm comparing to the control (51.10 and 8.35, respectively) This results supported previous work on cookies substituted with grapefruit and apricot kernel powder **(Seker *et al*., 2010; Khodaei *et al*., 2020).** This development could be attributed to the impact of wheat gluten and bagasse fiber on dough formulation. It has been reported that fruit wastes containing a significant amount of fiber absorb more water during dough preparation, hence limits the dough spread and cookies diameter with a concomitant increase in thickness **(Agrahar-Murugkar *et al*., 2015).** The spread ratio indicates the rising capacity of cookies, where a lower spread ratio implies better rising capacity. The thickness, diameter and weight of the cookie is in agreement with reported work of previous literatures **(Olapade and Adeyemo, 2014; Oyeyinka *et al*., 2018).**

Texture of breads was determined in terms of hardness property because of its relation with bread freshness and direct impact on customer acceptance. Results showed an increase in the hardness value with the increase in the percentage of addition of fibers and its PS ranged from 1372.23 g to 1998.23 g compared to the control (1164.23 g), and the highest value (1998.23 g) was recorded for FEC with 20% AIF-BP at PS of 170 µm. This result could be attributed to partial

Table 4. Physicochemical properties of the experimental FEC

BLOCK	TDF	IDF	SDF	Weight	Diameter	Thickness	Spread ratio	baking loss	Hardness (g)	L	a	b	ΔE
A1 (Central point, 3 replicate)	11.14^{e}	7.32^{e}	3.82^{e}	5.81^{e}	44.78^{f}	7.41^{e}	6.04^{f}	14.63^{e}	1656.23^{e}	34.56^{f}	6.57^{e}	12.53^{f}	27.02^{e}
A2	15.65^{c}	10.23^{c}	5.42^{b}	5.92^{c}	42.31^{h}	7.59^{c}	5.57^{h}	14.45^{g}	1819.23^{c}	32.72^{h}	7.42^{b}	11.60^{i}	28.63^{c}
A3	4.61^{i}	2.90^{i}	1.71^{h}	5.53^{i}	47.35^{b}	6.95^{i}	6.82^{b}	15.92^{a}	1372.23^{i}	38.21^{b}	5.77^{i}	13.35^{b}	24.16^{i}
A4	15.81^{b}	10.79^{b}	5.02^{c}	6.03^{b}	41.23^{i}	7.69^{b}	5.36^{i}	13.27^{i}	1911.23^{b}	31.69^{i}	6.83^{c}	11.87^{h}	29.42^{b}
A5	6.55^{g}	4.31^{g}	2.24^{h}	5.70^{g}	45.37^{d}	7.27^{g}	6.24^{d}	15.29^{b}	1491.23^{g}	36.24^{d}	5.85^{h}	12.93^{c}	25.73^{g}
A6	11.20^{d}	7.60^{d}	3.60^{f}	5.87^{d}	43.61^{g}	7.51^{d}	5.80^{g}	14.49^{f}	1722.23^{d}	33.51^{g}	6.37^{f}	12.57^{e}	27.81^{d}
A7	6.50^{h}	4.14^{h}	2.36^{g}	5.55^{h}	46.33^{c}	7.14^{h}	6.49^{c}	15.7^{c}	1454.23^{h}	37.03^{c}	6.21^{g}	12.82^{d}	25.18^{h}
A8	10.92^{f}	6.62^{f}	4.30^{d}	5.78^{f}	45.02^{e}	7.35^{f}	6.12^{e}	15.1^{d}	1588.23^{f}	35.56^{e}	6.59^{d}	12.32^{g}	26.39^{f}
A9	17.67^{a}	11.75^{a}	5.92^{a}	6.13^{a}	40.72^{j}	7.78^{a}	5.23^{j}	13.09^{j}	1998.23^{a}	31.56^{j}	7.82^{a}	11.59^{j}	29.44^{a}
Control	2.31^{j}	1.34^{j}	0.97^{j}	4.11^{j}	51.1^{a}	6.12^{j}	8.35^{a}	13.45^{h}	1164.23^{j}	65.21^{a}	4.12^{j}	30.84^{a}	-

Table 4. Sensory evaluation of the experimental FEC

BLOCK	Color	Taste	Aroma	Texture	Overall acceptability
A1 (Central point, 3 replicate)	8.35^{f}	8.48^{f}	7.15^{f}	6.92^{f}	7.72^{f}
A2	7.98^{h}	8.32^{h}	7.04^{h}	6.86^{h}	7.55^{h}
A3	9.34^{b}	8.89^{b}	7.67^{b}	7.25^{b}	8.29^{b}
A4	7.88^{i}	8.23^{i}	6.88^{i}	6.83^{i}	7.45^{i}
A5	8.94^{d}	8.73^{d}	7.36^{d}	7.01^{d}	8.01^{d}
A6	8.15^{g}	8.44^{g}	7.12^{g}	6.88^{g}	7.65^{g}
A7	9.20^{c}	8.85^{c}	7.42^{c}	7.20^{c}	8.17^{c}
A8	8.64^{e}	8.56^{e}	7.19^{e}	6.99^{e}	7.84^{e}
A9	7.03^{j}	8.21^{j}	6.81^{j}	6.80^{j}	7.21^{j}
Control	9.50^{a}	9.00^{a}	9.30^{a}	9.75^{a}	9.39^{a}

incorporation of AIF-BP with higher fiber content which restricts the expansion of gluten dough network structure during baking hence increasing the hardness of the cookies **(Ktenioudaki and Gallagher, 2012)**. Previous observation of increase in hardness of wheat cookies partially substituted with pumpkin powder has been reported **(Kulkarni and Joshi 2013)**. **(Oyeyinka *et al*., 2018)** reported higher hardness values (20.23- 64.85 N) for cookies prepared from fermented cassava roots compared to values recorded in this study. Variation in cookie hardness may be attributed to the differences in the ingredients used including starch component of the cassava roots.

Color parameters provide information about the consumer's acceptability and his purchase decision of the product. Color changes would influence the organoleptic properties of fortified cookies. The color parameters of wheat cookies obtained were L* (65.21), a* (4.12), and b* (30.84). However, a decrease in L-values with AIF-BP addition at higher PS from 38.21 to 31.56 was observed in FEC comparing to the control (Table 4). The reduction in the L* value is associated with the development of the interaction between reducing sugars and proteins (Millard reaction) , and the caramelization of sugars under heat treatment **(Usman *et al*., 2020)**. A similar observation has been reported for cookies made from tomato waste **(Bhat *et al*., 2016)**. For the a*, which measures the redness (+) to greeness (-). All FEC tend to be red. The higher portion of AIF-BP added at lower PS, the higher ammount of FEC redness was observed. The highest a value (7.82) was observed for FEC contained 20% AIF-BP powder at PS of 170 µm compared to the control (4.12). b* value represent the yellowness (+) to blueness (-). It could be noticed that as portion of AIF-BP decreased at higher PS, the higher ammount of yellowness of FEC were observed. The highest b value (13.35) was obtained for bread contained 13% AIF-BP at PS of 170 µm compared to the control (30.84). Regarding to changes in color ΔE, the experimental FEC show drastic colour changes due to having a relatively high amount of AIF-BP at high PS. The highest color change (29.44) was obsrved for FEC contained 20% AIF-BP powder at PS of 170 µm, meanwhile the lowest color change (24.16) was obsrved for bread contained 3% AIF-BP powder at PS of 170 µm (Table 4).

Sensory Evaluation

It was shown that AIF-BP addition and its PS had an inverse significant effect on all of the FEC sensory properties. All the sensory attributes evaluated (color, taste, aroma, texture and overall acceptability) of the experimental FEC scored more than six points, meaning that these FEC were acceptable.

Referring to the attributes of color, taste and aroma of bread samples, results showed consumer high preference score (higher than 6) comparing to control cookies. The highest score of color, taste, aroma, texture and overallacceptability were 9.34, 8.89, 7.67, 7.25 and 8.29, respectively for FEC contained 3% AIF-BP powder at PS of 170 µm was close to control. It is noted that the texture scores were the lowest among the measured sensory characteristics. This is because with the increase in the portion of AIF-BP added as well as its PS, the degree of firmness of FEC increase, which is not desirable to consumers. In terms of texture, results show that FEC contained 3% AIF-BP powder at PS of 170 µm had the most acceptable rate (7.25), meanwhile bread contained 20% AIF-BP powder at PS of 170 µm was the least accepted (6.80). According to the sensory evaluation, the conditions of the most acceptable FEC which could be recommended were as follows: FEC contained 3% AIF-BP powder at PS of 170 µm (8.29); FEC contained 6% AIF-BP powder at PS of 78 µm (8.17); FEC contained 6% AIF-BP powder at PS of 262 µm (8.01).

Conclusion

This study analyzed the properties of alcohol insoluble fraction of banana processing by-product and its impacts in manufacturing of wheat flour cookies. The effects of different levels of AIF-BP addition and PS on rheological, chemical, and functional properties were investigated. Response surface methodology was used to optimize the fiber –enriched cookies. The results showed that increasing in AIF-BP incorporation at the experimental PS significantly increased the total dietary fiber content and its functionality of FEC. Additionally, consumers accepted the sensory properties of the experimental FEC across all levels of addition and PSs within the experimental ranges. However, dilution of the gluten network results in adverse effects such as decreased dough stability and weakness, leading to reduced spread ration but increase hardness.FEC contained 3% AIF-BP powder at PS of 170 µm (8.29); FEC contained 6% AIF-BP powder at PS of 78 µm (8.17); FEC contained 6% AIF-BP powder at PS of 262 µm (8.01) are recommended for industrial use.

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الدور الوظيفى للشق الغنى بالألياف من قشور الموز كمصدر للألياف الغذائية لإنتاج كوكيز غنيه بالألياف

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يتزايد الاهتمام بالألياف الغذائية بشكل متزايد كمكون ذو خواص وظيفيه خصوصا تلك التى تحضر من مخلفات التصنيع الغذائى. تهدف الدراسة الحالية إلى دراسه تأثير إضافة الشقوق غير القابل للذوبان في الكحول المحضرة من قشور الموز (AIF-BP) عند مستوى حجم جزيئات متفاوت (PS) على انتاج كوكيز غنيه بالألياف. اظهرت الدراسة ارتفاع محتوى IF-BP من الالياف الغذائية بالإضافة الى قدرتها العالية على ربط الماء والزيت بناءًا على حجم الجزيئات التجريبى المستخدم فى الدراسة. كما اظهرت نتائج الفارينوجراف انه ومع ارتفاع نسبه AIF-BP المضافm عند مستويات مرتفعة من حجم الجزيئات تزداد معها قيم امتصاص الماء (WA) ووقت تطور العجين (DDT) ودرجة ضعف العجين (DW) ولكن كان لهما تأثير عكسي على مؤشر ثبات العجين (DST). أظهرت النتائج انخفاضا في نسبه الانتشار وارتفاع فى قيمة الصلابة للكوكيز الغنية بالألياف مقترنا مع ارتفاع نسبه اضافه AIF-BP عند مستويات مرتفعه من حجم الجزيئات. أشارت النتائج الى القابليه الحسيه لجميع الصفات الحسيه لكل من الكوكيز الغنيه بالالياف والعينه القياسيه

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