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Impact of Solid State Fermentation on Chemical Composition, Functional Properties, and Antioxidant Activity of Wheat Bran

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Abstract

Wheat bran is the major by-product of wheat milling, as it is obtained in large amounts during cereal wheat, because of its limited appropriateness as a food ingredient, it is nowadays largely unexploited. This study was aimed to investigate the chemical composition, functional properties, and antioxidant activity of wheat bran fermented by lactic acid bacteria, and Saccharomyces cerevisiae as active dry yeast in the solid-state. Bioactive compounds (free, bound, and total phenolic acids), antioxidant activity, functional properties were evaluated. Likewise, water-extractable arabinoxylans and phytic acid degradation were determined in fermented and non-fermented wheat bran. After treatments, protein, fiber, ash, and fat contents in fermented bran were raised than non-fermented bran. Total, free phenolic content and antioxidant activity increased after solid-state fermentation. Phytic acid content decrement of 36.5% and water-extractable arabinoxylans increment four times were observed in fermented bran. As well as, protein solubility, water holding capacity, water-solubility, oil holding capacity of fermented wheat bran were improved. Thus, the solid-state fermentation is an efficient technique and can be applied to enhance the nutritional and functional properties of wheat bran, as well as utilized as ingredients in food applications.

Keywords
Wheat bran, Lactic acid bacteria, Saccharomyces cerevisiae, functional properties, Phytic acid, Phenolics, Antioxidant

INTRODUCTION

Wheat is one of the most widespread edible crops planted and consumed globally. Bran is the major by-product of wheat milling and is obtained in large amounts around 150 million tons annually. It has been recognized as a good source of proteins, minerals, and dietary fiber (Prückler *et al.*, 2014). In recent years, there is an increasing interest in the improvement of whole grain, due to increasing health attention between consumers and the food manufacturers. Whole grain has been shown to provide probable health advantages for humans. Previous studies reported that taking whole-grain cereals is able to reduce the risk of cardiovascular, diabetes, several cancers, and obesity (Reicks *et al*., 2014; Gaesser, 2020; Hu *et al* 2020). Therapeutic impacts were robustly connected with nutrient components including phenolic components, dietary fiber, as well as antioxidants current in the wheat bran (Li *et al.*, 2015), while these fragments were ousted through the production of refined wheat flour. To utilization of nutritional and bioactive compounds present in wheat bran, bran was re-added into refined wheat flour as a supplement to make whole wheat flour, but it induced numerous negative impacts on sensory quality, technological properties, and dough rheology (Sozer., 2014; Boita *et al*., 2016; Liu *et al*., 2016).

The outer layers of wheat kernel include lignin and cellulose, which impact both the taste and mouthfeel. Bran complementation's generally weakened the gluten network structure and then influence the gas-holding capacity of the dough, hence causing a lowering in volume and elasticity of baking food (Coda *et al*., 2014). Furthermore, the lower shelf-life of whole flour in comparison with refined flour limits its use in food manufacture. This may be due to lipids and lipid metabolizing enzymes are present in wheat bran which causes lipid degradation and rancidity during storage (Li *et al*., 2016).

Phytic acid is considered an anti-nutrient factor in bran for its direct or indirect ability to bind minerals and change their solubility, digestibility, absorption, and functionality, which involve of bioavailability of minerals (Dai *et al*., 2007). Arabinoxylans are the main components of cell walls in cereal grains. They can be separated as water-extractable arabinoxylans (WEAX) and water unextractable arabinoxylans (WUAX). WUAX are negative effects on bread making WEAX with medium to high molecular weight have a positive impact on loaf volume (Zhang *et al*., 2014a). water unextractable arabinoxylans which make up 70% of wheat endosperm cell walls (Vardakou *et al*., 2004) can be hydrolyzed by endoxylanases causing them to lose their strong water holding capacity (Courtin and Delcour, 2002).

To resolve the troubles induced by added bran in whole wheat flour, many investigations have concentrated on modifying features of wheat bran. Numerous investigations have highlighted that high moisture fermentation of wheat bran with lactic acid bacteria (LAB) or yeast, is a useful pre-treatment process to enhance technological, nutritional, and sensory properties of bran-containing products (Coda *et al*., 2014; Spaggiari et al., 2020), and to reduce anti-nutritive factors like phytic acid as well as enhancing mineral bioavailability (Zhao *et al*., 2017). Bran fermentation improves bioavailability and the contents of various functional compounds such as total free phenols, WEAX, and soluble fiber (Tu *et al*., 2020; Ma *et al*., 2021), as well as improving functional properties of wheat brain (Chu *et al*., 2019). Furthermore, high moisture fermentation will cost vast energy to remove the water before adding bran into wheat flour. Therefore, the aim of the current study was to modify autoclaved wheat bran by solid-state fermentation with yeast and LAB. As well as an investigation the effects on gross chemical composition, functional properties, phenolics, phytic acid contents, and antioxidant activity of wheat bran.

MATERIAL AND METHODS

1. Raw materials

Commercial wheat bran was obtained from Alshuruq Mills (Assiut City, Egypt), *Saccharomyces cerevisiae* as active dry yeast (Commercial baker's yeast with high sugar tolerance) was obtained from local market, and *Lactobacillus plantarum* ATCC 14917 was purchased from Microbiological Resources center (MIRCEN) Ain Shams University, Cairo, Egypt.

2. Inoculant preparation

Lactobacillus bacteria strains (*Lactobacillus plantarum*) were activated by inoculating in sterile MRS broth (9 ml) and incubation at 37 °C for 24 h. The cells were separated from the broth by centrifuging and re-suspended in sterile saline solution (9 ml) with final concentration 10^8 CFU/mL (Ujiroghene *et al*., 2019). Active dry yeast was used directly without incubation.

3. Solid-state fermentation

The fermentation processes of autoclaved wheat bran (121°C at 15 min), was curt out as follows:

Group I treated by *L. plantarum*

The autoclaved water was added to wheat bran (2:1), the activated culture of probiotic bacteria (10^8 CFU/mL) was added to autoclaved bran by a concentration of 1% and incubated at 37 °C for 24 and 48h.

Group II treated by yeast

The autoclaved water was added to wheat bran (2:1) and 1.25% active dry yeast was mixed well and fermented for 24 and 48h.

Group III treated LPY

The autoclaved water was added to wheat bran (2:1), the activated culture of probiotic bacteria (10^8 CFU/mL) was added to autoclaved bran by a concentration of 1% and 1.25% active dry yeast was mixed well and fermented for 24 h and 48h. Wheat bran autoclaved and non-autoclaved samples without starters were incubated at 37 °C and used as control. After fermentation all samples were air-dried, then milled by a laboratory mill (Braun, Germany) to pass through a 60-mesh sieve and stored at -20°C until analyses.

4. Gross chemical composition of wheat bran

The chemical composition of fermented and non-fermented wheat brans including protein, fat, fiber, and ash contents were determined according to the methods described in A.O.A.C. (2000). Carbohydrate was calculated by difference.

5. Phytic acid

The phytic acid was determined in terms of its phosphorous content, using the method described by Kent-Jones and Amos (1957).

6. phenolic compounds

Total phenolic content was extracted from wheat bran samples using methods described by the method of Abdel-Gawad (1982), while free phenolic compounds were extracted according to (Adom *et al.*, 2003). Total and free phenolic content determined by the Folin–Ciocalteu's method according to (Singleton *et al*., 1998). The results were expressed as milligrams of gallic acid equivalents (GAE) per100 gram of bran sample on dry weight basis. Bound phenolic compounds were calculated by subtract free phenolics from total phenolics.

7. Determination of antioxidant activity

Samples were extracted using methods described by Zielijski *et al*., (2008). The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay was carried out according to the method described by Lee *et al*., (2003) with some modifications. The stock reagent solution (10^{-3} Mol) was prepared by dissolving 22 mg of (DPPH) in 50 ml of methanol and stored at 20°C until use. The working solution (6×10^{-5} Mol) was prepared by mixing 6 mL of stock solution with 100 mL of methanol to obtain an absorbance value of 0.8±0.02 at 515 nm, as measured using a spectrophotometer (6505 UV/Vis, Jenway LTD., Felsted, Dunmow, UK). Extract solution of tested samples (0.1 ml) were vortexes for 30 s with 3.9 ml of DPPH solution and left to react for 30 min, in the dark after which the absorbance was measured at 515 nm and recorded. A control with no added extract was also analyzed. Scavenging activity was calculated as follows:

DPPH radical scavenging activity (%) =

[(Ab control - Ab sample) / Ab control] X 100

Where: Ab is the absorbance at 515 nm.

8. Water extractable arabinoxylans (WEAX)

The WEAX was determined following previous study (Douglas, 1981) by extracting 0.4 g of bran samples with 20 mL of distilled water at room temperature. The extracts were centrifuged at 5000 rpm for 10 min. 100 µL of supernatant, 100 µL of distilled water and 2 mL of freshly prepared reaction solution (1 g phloroglucinol in 5 mL anhydrous ethanol, 2 mL chlorohydric acid, 110 mL acetic acid, 1 mL 17.5 g/L glucose solution) were pipetted into stoppered glass tube. The tubes were vigorously boiling in water bath for 25 min and then cooled in flowing water immediately. The absorbance was measured at 552 nm and 510 nm successively. D- (+)-Xylose was used as standard. Calculate the content of WEAX by subtraction of

the absorbance at 510 nm from 552 nm and comparison of the results with a standard curve and conversion of D-(+)-xylose to pentosan with a scaling factor (0.88).

9. pH value

The pH of the samples was determined according to approved methods 02-52 and 02-31 (A.A.C.C., 2000). one gram of fermented and non-fermented wheat brans was first diluted and homogenize in 10 ml of distilled water then the pH of suspension was measured by a pH meter (Hanna Instruments, Padova, Italy).

10. Functional properties

Water-holding capacity and water solubility was achieved according to the method of Singh and Singh (2003). Oil Holding Capacity was determined according to the method described by Sosulski *et al*. (1976). The protein solubility was achieved according to the method of Morr *et al*. (1985).

11. Statistical analysis

Data were analyzed statistically by one-way analysis of variance (ANOVA) using SPSS software (IBM SPSS Statistics, version 22). When the difference between the samples was statistically significant ($p < 0.05$), the Duncan test was used to determine the differences among the mean.

RESULTS AND DISCUSSION

Chemical composition

Effect of fermentation on gross chemical composition of wheat bran is presented in Table 1. It was observed that the protein content of raw wheat bran (WBR) was 23.46% and decreased after autoclaving to 23.08% was not significantly different ($p < 0.05$), which may be caused by the Maillard reaction which occurred under a high temperature in the autoclave. Furthermore, fermentation of wheat bran increased protein content, and the highest values were recorded as follows: 24.95% > 24.52% > 24.20% > 23.89% for WBYP 48h, WBYP 24h, WBY 48h, and WBP 48h respectively, similar results were found by (Hassan *et al*., 2008; Zhao *et al*., 2017; Ye *et al*., 2021). It's been known, yeasts and lactic acid bacteria have some proteinases and peptidases (Hata *et al*., 2014). Likewise, the fiber, ash and fat content of fermented bran increased compared with autoclaved wheat bran (WBA). The increase in protein, fiber, fat, and ash content was primarily due to the reproduction of yeast or lactic acid bacteria during fermentation. Additionally, protein, ash and fat percentage of non-fermented wheat bran is almost like that reported by Ye *et al*., (2021).

Free, bound, and total phenolic content and antioxidant activity of wheat bran.

The phenolic compounds and antioxidant activity of wheat bran are shown in Table 2. From the results, it was observed that total, bound, and free phenols content were reduced after autoclaving by 107.03, 83.26, and 23.77 mg GAE/100g respectively for WBA, this decrease in the phenolic compound may be due to it is high sensitivity to a higher temperature, leading to a reduction in its content during the thermal treatment. These results closely agree with those reported by (Zhao *et al*., 2017). Furthermore, total, and free phenols were increased while, bound phenolics was decreased after fermentation. The highest total and free phenolic content of modified bran were recorded in the order as follows: WBYP48h > WBP48h > WBY48h. The majority of the phenolic compounds, especially phenolic acids, form cross-links with polysaccharides in wheat brans. The phenolic acids can be released by hydrolyzing the brans under acidic conditions (Kim *et al*., 2006). During wheat bran fermentation, acidification caused the increment of phenolics (Total and free) after autoclaving. The highest concentration of total phenolic content was observed in WBYP48h (494.44 mg GAE/100g), while total phenolic content was lowest in WBP24h (453.14 mg GAE/100g) of fermented wheat bran.

Regarding antioxidant activity results (Table 2), the antioxidant activity of wheat bran was increased significantly ($P<0.05$) after fermentation. The WBP48h and WBYP48h samples had the highest values of antioxidant activity, while WBR had the lowest. The increasing of antioxidant activity is most due to phenolic compounds, although a minor contribution could be also due to other compounds which could have antioxidant potential such as peptides and amino acids, or also

to newly formed/released bioactive compounds produced by the lactic acid bacteria metabolism. Overall, the total phenolic content and antioxidant activity reported in this study are in same line with other investigations (Zhang *et al*., 2014b; Nordlund *et al*., 2013; Spaggiari *et al*., 2020).

Water extractable arabinoxylans

Arabinoxylans are essential combinations that describe the structure of plant cells, specifically those of grain cereals. They exist in both insoluble-water and soluble states, numerous investigations have suggested that the soluble-formal has positive results on rheological characteristics of dough (Courtin & Delcour, 2002). After autoclaving and fermentation, the content of water-extractable arabinoxylans in bran improved significantly ($P<0.05$) Fig. 1, increased from 10.88 (WBR) to 48.40 (WBY48h). This enhancement means that autoclaving, as well as fermentation, could be caused the transition from water unextractable arabinoxylans to water-extractable arabinoxylans partly. Water extractable arabinoxylans in bran increased after fermentation, and the highest content was observed in WBY48h (48.40 mg/g), WBYP48h (48.14 mg/g), WBYP24h (37.25 mg/g), and WBY24h (37.16 mg/g), while the lowest 26.50 mg/g was for WBP24h, Similar results have been previously reported by (Zhao *et al*., 2017; Spaggiari *et al*., 2020).

Effect of fermentation on the phytate content

Wheat bran and the outer layers of cereal grains, in general, have a lot of phytates, despite being high in bioactive chemicals, which have been identified as anti-nutritive compounds that reduce the bioavailability of essential minerals in the diet including Fe2+, Ca2+ Zn2+, Mg2+, and amino acids (Carrizo et al., 2016). Hence, phytic acid and phytate breakdown are advantageous from a nutritional standpoint in order to improve mineral bioavailability. Phytate phosphorus and phytic acid degradation results are shown in Table 3. It has been observed that the autoclaving stage did not remarkably change the phytic acid content of WBR. In contrast, fermented wheat bran led to a decrease in the phytic acid content, and the highest phytate degradation (36.51%) was recorded in WBP48h, followed by WBYP48h (28.17%), WBY48h (22.22%), WBY24h (12.70%), and the lowest 4.36% was recorded in WBA, whereas phytate degradation was zero in WBC, these results are in the line with (Spaggiari *et al*., 2020). Phytic acid degradation may be due to phytase, and phosphatase enzymes present in microorganisms which can hydrolyze the phytic acid expressed in *Lactobacillus rhamnosus*1473, as previously reported in strains of the same species (Zamudio, *et al.*, 2001 Carrizo *et al*., 2016). Also, the endogenous phytases present in wheat bran are probably inactivated after autoclaving. Results regarding the pH value (Table 3); was observed that A considerable decrease in pH values was (from 6.64±0.04 to 4.50±0.13).

Functional properties

1. Hydration properties

The effect of fermentation on water-Holding capacity (WHC) and water solubility (WS) of wheat bran are shown in Table 4. The WHC of raw what bran WBR was 247.55%, and autoclaving and fermentation increased the WHC of wheat bran significantly ($p <0.05$), the highest WHC was recorded in WBYP48h (259.31%), followed by WBP48h (258.77%), WBY48h (258.48%) and WBYP24h (256.56%). while the lowest was in WBA (251.25%), Similar results have been previously reported by (Zhao *et al*., 2017; Ye *et al*., 2021). These results demonstrate that all fermentation can be improving the WHC of wheat bran. This increase in WHC may be due to an increment of soluble dietary fiber because it can absorb more water than insoluble dietary fiber. Previous studies reported that fermentation with lactic acid bacteria or yeast can improve the content of soluble dietary fiber, which also has been proved in wheat bran (Zhao *et al*., 2017), and rye sourdough production (Mihhalevski *et al*., 2013). Furthermore, water solubility (WS) of non-treated wheat bran was12.85%, and it was significantly enriched up to 16.39% (table. 4) after fermentation processes ($p <0.05$). This increase in WS of modified wheat bran could be due to the increase of soluble dietary fiber.

Table (1) Gross chemical composition of fermented and non-fermented wheat brans (D.W bases)

Treatments	protein	fiber	Ash	fat	Carbohydrate*
WBR	23.46±0.46^{b}	8.98±0.13^{cd}	4.98±0.17^{d}	4.31±0.14^{c}	58.27±0.63^{a}
WBA	23.08±0.92^{b}	8.76±0.29^{d}	5.30±0.21^{c}	4.49±0.19^{c}	58.37±0.36^{a}
WBY24h	23.78±0.68^{ab}	9.28±0.22^{bcd}	5.38±0.09^{c}	5.05±0.10^{ab}	56.51±0.49^{b}
WBY48h	24.20±0.72^{ab}	9.62±0.03^{bc}	6.00±0.06^{ab}	5.35±0.35^{a}	54.83±6.45^{c}
WBP24h	23.72±0.78^{ab}	8.98±0.14^{cd}	5.15±0.13^{cd}	5.22±0.08^{ab}	56.93±5.70^{ab}
WBP48h	23.89±0.89^{ab}	9.56±0.28^{bc}	5.35±0.40^{c}	5.30±0.31^{ab}	55.90±6.54^{bc}
WBYP24h	24.52±0.52^{ab}	10.01±0.25^{b}	5.79±0.10^{b}	4.89±0.29^{b}	54.79±4.77^{c}
WBYP48h	24.95±0.95^{a}	11.24±0.96^{a}	6.27±0.05^{a}	5.23±0.23^{ab}	52.31±7.4^{6d}

*Carbohydrate by deference

Values are the mean of triplicate determinations with standard division.

The different letters at the column means significant differences at ($p \leq 0.05$) and the same letters means no significant differences

Table (2) Effect of fermentation on phenolic compounds and antioxidant activity of wheat bran

Treatments	Total phenolic content mg/100g			Antioxidant activity (%)
	Free	Bound	Total	
WBR	222.56±0.56^{d}	322.47±5.56^{a}	545.03±5.00^{a}	5.84g±0.16^{g}
WBA	198.79±0.79^{e}	239.21±1.45^{c}	438.00±2.13^{e}	6.13f±0.07^{f}
WBY24h	176.77±2.23^{g}	271.22±4.91^{b}	447.99±2.84^{d}	6.88±0.08^{e}
WBY48h	289.33±3.67^{b}	181.27±5.02^{e}	470.60±2.53^{c}	11.46±0.06^{c}
WBP24h	322.08±2.08^{a}	131.06±5.06^{g}	453.14±7.14^{d}	7.50±0.03^{d}
WBP48h	323.87±1.13^{a}	148.43±4.17^{f}	472.30±5.30^{c}	14.45±0.07^{a}
WBYP24h	185.34±3.66^{f}	278.01±1.34^{b}	463.35±3.33^{c}	7.37±0.05^{d}
WBYP48h	271.39±4.39^{c}	223.05±6.45^{d}	494.44±6.08^{b}	12.89±0.04^{b}

Values are the mean of triplicate determinations with standard division.

The different letters at the column means significant differences at ($p \leq 0.05$) and the same letters means no significant differences

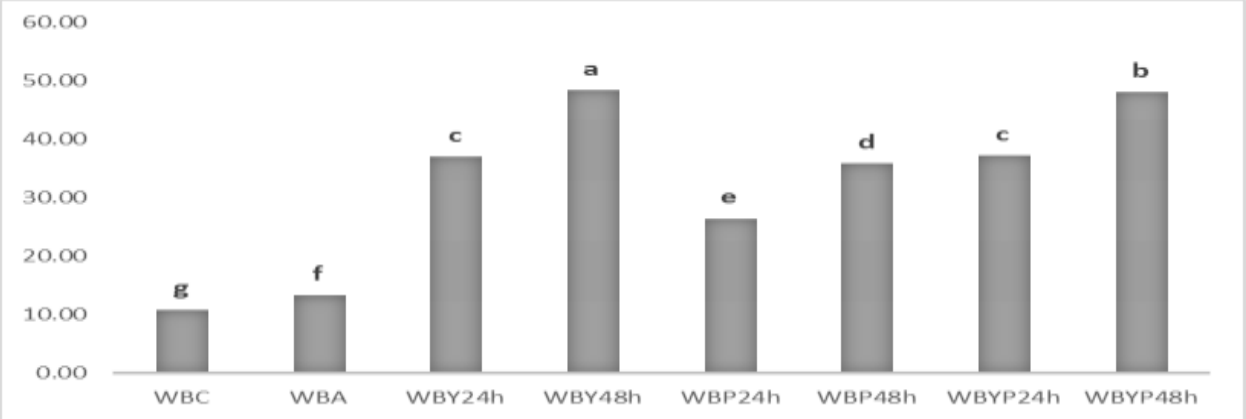

Fig. 1. Water extractable arabinoxylans (mg/g) of wheat brans.

Abbreviations: **WBR** raw bran; **WBA** autoclaved wheat bran; **WBY24h** fermented autoclaved bran with yeast for 24h; **WBY48h** fermented autoclaved bran with yeast for 48h; **WBP24h** fermented autoclaved bran with L. *plantarum* for 24h; **WBP48h** fermented autoclaved bran with L. *plantarum* for 48h; **WBYP24h** fermented autoclaved bran with L. *plantarum* and yeast for 24h; **WBYP48h** fermented autoclaved bran with L. *plantarum* and yeast for 48h.

Table (3) Effect of fermentation on phytic acid content and pH values of wheat bran

Treatments	Phytate phosphorus %	Phytic acid degradation %	Phytic acid %	pH
WBR	0.71±0.07^{a}	00	2.52±0.24^{a}	6.64±0.04^{a}
WBA	0.68±0.10^{ab}	4.36	2.41±0.36^{ab}	6.63±0.05^{a}
WBY24h	0.62±0.00^{bc}	12.70	2.20±0.13^{bc}	6.30±0.09^{b}
WBY48h	0.55±0.01^{cd}	22.22	1.96±0.18^{cd}	5.86±0.10^{c}
WBP24h	0.59±0.09^{c}	16.71	2.10±0.15^{c}	5.47±0.07^{d}
WBP48h	0.45±0.05^{e}	36.51	1.60±0.42^{e}	4.50±0.13^{f}
WBYP24h	0.59±0.02^{c}	17.06	2.09±0.22^{cd}	5.95±0.05^{c}
WBYP48h	0.51d±0.03^{e}	28.17	1.81±0.56^{de}	5.30±0.11^{e}

Values are the mean of triplicate determinations with standard division.
The different letters at the column means significant differences at ($p \leq 0.05$) and the same letters means no significant differences

Table 4. Functional properties of fermented and non-fermented wheat brans (D.W bases)

Treatments	Water holding capacity (%)	water solubility	Oil holding capacity (%)	soluble protein as % of total sample protein
WBR	247.55±90^{e}	12.85±0.15^{de}	210.96±0.94^{d}	11.14±0.87^{d}
WBA	251.25±1.75^{d}	12.39±0.61^{e}	211.20±0.80^{d}	12.88±0.28^{c}
WBY24h	255.20±1.80^{c}	13.11±1.06^{cde}	215.00±2.00^{c}	13.64±0.34^{c}
WBY48h	258.48±1.52^{ab}	15.48±0.80^{ab}	219.59±1.41^{b}	15.27±0.73^{b}
WBP24h	255.21±1.92^{c}	13.86±0.36^{cd}	214.27±0.73^{c}	14.07±0.93^{c}
WBP48h	258.77±1.23^{ab}	14.30±0.70^{bc}	219.67±1.60^{b}	16.30±0.70^{ab}
WBYP24h	256.56±2.10^{bc}	14.18±0.90^{c}	221.88±1.88^{a}	13.31±0.69^{c}
WBYP48h	259.31±1.65^{a}	16.39±0.61^{a}	222.42±1.42^{a}	16.84±0.44^{a}

Values are the mean of triplicate determinations with standard division.
The different letters at the column means significant differences at ($p \leq 0.05$) and the same letters means no significant differences.

Abbreviations: WBR raw bran; **WBA** autoclaved wheat bran; **WBY24h** fermented autoclaved bran with yeast for 24h; **WBY48h** fermented autoclaved bran with yeast for 48h; **WBP24h** fermented autoclaved bran with L. *plantarum* for 24h; **WBP48h** fermented autoclaved bran with L. *plantarum* for 48h; **WBYP24h** fermented autoclaved bran with L. *plantarum* and yeast for 24h; **WBYP48h** fermented autoclaved bran with L. *plantarum* and yeast for 48h

2. *Oil holding capacity*

The results in Table 4 are shown the effect of fermentation on Oil-Holding capacity (OHC) of wheat bran. After-fermentation the OHC of bran was enhanced obviously. The mean values showed higher oil holding capacity for WBYP48h (222.42%), followed by WBYP24h (221.88%), WBP48h (219.67%) and WBY48h (219.59%), while the lowest 210.96% was found in WBR. It has been found that surface area and hydrophobicity are improving oil holding capacity (Chau and Cheung 1997).

3. *Protein solubility*

The proteins solubility was determined because it plays an important role in the functional and structural features of wheat bran. Protein solubility is a key factor in dietary protein functionality and a reliable indicator of protein application potential. It was mentioned that the protein solubility has a strong association with foaming and emulsifying properties (Wouters *et al*., 2016). The protein solubility of wheat bran is illustrated in Table 4. The protein solubility of raw what bran (WBR) was 11.14%, while autoclaving and fermentation processes increased the soluble protein of wheat bran significantly ($p < 0.05$). The highest values were recorded as follows: 16.84% > 16.30% > 15.27% > 14.07% for WBYP48h, WBP48h, WBY48h, and WBP24h, respectively. These results are in line with those reported by (Arte et al., 2015). These increasing in soluble protein, maybe due to degradation of proteins in wheat brans after fermentation process of wheat bran treatment by yeast or lactic acid bacteria. It has been reported that Lactic fermentation enhanced indirectly protein hydrolysis via endogenous proteases (Dallagnol et al., 2013).

CONCLUSION

In conclusion, solid-state fermentation is an efficient technique that can improve the nutritional and functional properties of wheat bran. After fermentation, protein, fiber, ash, fat contents as well as phenolic compounds, and antioxidant activity were increased. Phytic acid content in wheat bran was decreased partly, while water-extractable arabinoxylans and protein solubility increased significantly ($p < 0.05$). In addition, functional properties of fermented wheat bran including water-solubility, water-holding capacity, oil holding capacity were improved. it's potential to utilize the modified wheat bran by solid-state fermentation as functionality ingredients or reproduction whole wheat flour via added modified wheat bran to wheat flour.

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الملخص العربي

تأثير تخمر الحالة الصلبة على التركيب الكيميائي، والخصائص الوظيفية ، ونشاط مضادات الاكسده لردة القمح

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تعتبر ردة القمح المنتج الثانوي الرئيسي لطحن القمح حيث يتم الحصول عليها بكميات كبيرة أثناء طحن الحبوب ، ولكن بسبب محدودية ملاءمتها كمكون غذائي ، مما يجعلها غير مستغلة إلى حد كبير فى الوقت الحاضر. لذا أجريت هذه الدراسة بهدف تقييم تأثير التخمر بواسطة بكتيريا حمض اللاكتيك، و خميرة الخبازعلى الخواص الكيميائية و الوظيفية ومضادات الاكسده لردة القمح. حيث تم تقدير المركبات النشطة بيولوجيا (الأحماض الفينولية الحرة ، المرتبطة ، الكلية) ونشاط مضادات الاكسده و الخواص الوظيفية. وكذلك تم تقديرحمض الفيتيك و الارابينوزيلان القابلة للذوبان فى الماء لكل من ردة القمح الخام والمعدلة بالتخمر. ولقد أظهرت النتائج ارتفاع نسبة البروتين والألياف والرماد والدهون لردة القمح المعدلة بالتخمر عن تلك الموجودة فى الردة الخام. وكذلك ارتفعت نسبة المركبات الفينولية والحرة و والنشاط المضاد للاكسده بعد عمليات التخمر. وبالإضافة الى ذلك انخفضت نسبة حمض الفيتك الى 36.5٪، بينما ارتفعت نسبة الأرابينوزيلان القابلة لذوبان فى الماء أربع مرات للردة المعدلة. وكذلك أظهرت النتائج تحسن الخواص الوظيفية للردة المعدلة، حيث ارتفعت نسب القدرة على الاحتفاظ بالماء ، والقابلية للذوبان في الماء، والقدرة على الاحتفاظ بالزيت و ذوبانية البروتين. وبالتالي، فإن تخمر الحالة الصلبة يعتبرمن الطرق الفعالة والتى يمكن تطبيقها لتحسين الخواص التغذوية والوظيفية لردة القمح ، مما يزيد من استخدامها كمكونات في التطبيقات الغذائية.