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Egyptian Balady Bread Quality as Affected by Functional Nano-Powders of Some Food Industry by-Products

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THE USE of nano-material as delivery system in nutritional supplements is a promising technology to improve the bioavailability of their bioactive compounds. In this study, five food by-products "nano wheat bran (NWB), nano wheat germ (NWG), fermented nano-rice bran (FNRB), fermented nano-carrot pomace (FNCP) and fermented nano-pomegranate peel (FNPP)" were prepared and used as natural sources of bioactive compounds in the preparation of functional Egyptian balady bread. Nano and fermented nano-materials were used at 5, 15 and 25% replacement levels of wheat flour basis. Organoleptic characteristics, staling test and color attributes of balady bread were studied. The results of alkaline water retention capacity (AWRC) test, as a bread staling indication, revealed that all tested nano-materials showed positive effect on retarding staling of bread during storage at room temperature up to 72h and the bread was better than control regarding freshness properties. The color attributes of balady bread revealed remarkable differences between control and tested samples. Addition of fiber materials significantly decreased L* values, while a* values increased. Organoleptic test results showed that partially replacing of wheat flour 72% extraction by 25% NWB, 25% NWG, 15% FNRP, 5% of FNCP and 5% FNPP still providing a good quality of functional Egyptian balady bread.

Keywords: Food by-products, Solid state fermentation, Nanotechnology, Balady bread quality.

Introduction

Recently, healthy nutrition has become a growing demand worldwide and thus, the production of several nutritional food products with healthy benefits. Industrial food by-products are rich sources of functional compounds for improving the nutritional value of ordinary baked products and promoting their health properties (Martins et al., 2017). Phytochemicals, vitamins, fibers and minerals among others are functional ingredients, could be prepared from cheap sources as food industries by-products (Belghith et al., 2016a and Ben Jeddou et al., 2017). The incorporation of such ingredients has technological, nutritional and health promoting impacts on baked products. Health promoting properties of supplemented bakery products were discussed by several review articles (Ktenioudaki and Gallagher, 2012; Rawat and Indrani, 2015 and Sharma et al., 2016). Specific by-products fortification, namely wheat bran (Hemdane et al., 2016 and Onipe et al., 2015), cereal bran (Heiniö et al., 2016) and fruit pomace (Quiles et al., 2016; Derakhshan et al., 2018 and Parvin et al., 2019) were also discussed.

Food nano-technology affects the bioavailability of functional ingredients in food products and consequently its nutritional value (Srinivas et al., 2010). As recognized, the biological activities of nano-materials (including their toxicological aspects) are basically

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dependent on their phytochemical constituents (Hwang et al., 2012 and He et al., 2015). The applicable areas of nano-technology in food industry include food security and safety aspects, extending shelf life, development of aroma and nutrient vehicles and serving functional foods (He and Hwang, 2016). At nano-scale, the structure and surface area of particles were altered bringing some new characteristics. These new characteristics (quantum, optical, magnetic, and catalytic characteristics), compared with the normal size, give the nano materials new industrial applications (Huang et al., 2007 and Zhao et al., 2009).

Available review articles are suggesting the pre-treatments of food industry by-products, such as fermentation, enzymatic heat treatments or ultra-fine grinding, that may enhance bioaccessibility of phenolics and minimize the negative effects as well as improving the health beneficial properties (Penella et al., 2008; Moore et al., 2007; Chau et al., 2007; Dordevic et al., 2010; Oliveira, 2012 and Rosa et al., 2013). Prabhu et al. (2014) evaluated the phytochemicals and antioxidant properties of rice bran fermented for 24 and 48 hr. Their results revealed that yeast fermentation significantly increased the phenolic contents by 23% and 24%, flavonoid contents by 14% and 18%, respectively. Yeast fermentation also decreased tannin content, which is an anti-nutritional factor, with about 27%. Regarding antioxidant activity, fermented rice brans showed 56% and 49% radical scavenging activity and 57 and 17% total antioxidant activity with 24 and 48-hr fermentation, respectively.

Balady bread is the popular type of bread among the Egyptian and Middle East consumers. Balady bread is a flat and circular loaves (30 cm diameter and 1cm thickness) consisting from upper (crust) layer and bottom layer. Balady bread dough is softer (70-75% water) compared to other bread types and has lower protein content. Soft dough is fermented to 2h then baked at high temperature (400-500 ºC) for 1-2 min. During baking gasses expansion takes place resulting in tow layers and thus called oven spring. Balady bread has higher surface area and higher crust/crumb ratio due to it has very small crumb layer (Yaseen et al., 2007).

The present study was carried out to develop sustainable methods such as solid-state fermentation and superfine grinding (nano- size) as well as the combination between them in order to modify the structure of tested food by-products (wheat bran, wheat germ, rice bran, carrot pomace and pomegranate peel). Moreover, wheat flour was substituted using the obtained nano and fermented nano-food by-products.

Materials and Methods

Materials

Wheat flour (72%), Wheat flour (82%), whole-meal wheat, wheat bran and wheat germ were obtained from North Cairo Flour Mills Company, Egypt. Rice bran was obtained from Rice Research and Training Centre, Sakha, Kafr El-Sheikh, Egypt. Carrot (*Daucus carota*) and pomegranate fruits (*Punica granatum* L.) were purchased from the local market, Giza, Egypt. Active dry yeast (*Saccharomyces cerevisiae*) was obtained from Egyptian Sugar and Integrated Industries Company (ESIIC), Chemicals Factory, El-Hawamdia City, Giza, Egypt.

Methods

Stabilization of wheat germ and rice bran

Wheat germ and rice bran were stabilized in a hot air-oven at a temperature of 120±2 °C for 1 min according to Younas et al. (2011). The stabilized wheat germ and rice bran were ground using Moulinex grinder (Moulinex 753, Mexico) to pass through a 40-mesh (420µm) and packed in polyethylene bags and stored at -30 °C until use.

Preparation of carrot pomace

Carrot pomace was obtained after juice extraction (Juice extractor, Moulinex 753, Mexico). Carrot pomace was dried in an air-oven at 50±1 °C for 16 h. The dried sample was ground using Moulinex grinder and passed through a 40-mesh sieve and packed in polyethylene bags and stored at -30 °C until use.

Preparation of Pomegranate peel

The peel of Pomegranate was manually removed and dried in an air-oven at 50±1°C for 16h. The dried sample was ground using Moulinex grinder and passed through a 40-mesh sieve and packed in polyethylene bags and stored at -30°C until use.

Solid-state yeast fermentation

Yeast strain (*Saccharomyces cerevisiae* FC-620) was obtained from Microbial Chemistry Dept. Collection, National Research Centre, Dokki, Cairo, Egypt. The yeast cells were activated, a loopful of the culture was transferred to 250mL Erlenmeyer flask containing 50 mL broth medium (0.3% yeast extract, 0.3% malt extract, 0.5%

peptone and 5% sucrose) and incubated for 24 hr at 32°C under shaking condition. Solid-state yeast treatment was carried out according to the method of Moore et al. (2007) as follows: 50 mL of yeast preparation (1380 cfu/mL) was mixed with 100g sample in a sterile conical flask. Flasks were sealed with cotton seals and incubated at 32°C for 48h. All treated samples were dried at 50±1 °C for 16 h and stored in polyethylene bags at -30°C until use.

Preparation of nano and fermented-nano materials

The raw wheat bran and wheat germ and fermented rice bran, carrot pomace and pomegranate peels were ground using 5 mm zirconium oxide ball and zirconium oxide bowl volume 250 mL in a PM 100 Planetary Ball-mill (Retsch, Germany) as described by Zhu et al. (2010) with some modifications. Samples (150g) were ground at 30Hz frequency for 60 min at room temperature.

Transmission Electron Microscopy (TEM)

All ground samples were examined with a JEOL JX 1230 technique with micro analyzer probe, Japan. This technique was used to determine the particle size of the investigated samples according to Casuccio et al. (2004).

Preparation of functional formulas

Nano- wheat bran, nano-wheat germ, fermented-nano rice bran, fermented-nano carrot pomace and fermented-nano pomegranate peel were used to replace wheat flour (72% extraction) at 5, 15 and 25% levels. Control samples were made from wheat flour 72% extraction, 82% extraction and whole-meal flourfor comparison as shown in Table 1.

TABLE 1. Preparation of Egyptian balady bread formulas (g/100 g).

*Formula No.	*Wheat flour extraction (%)*			NWB	NWG	FNRB	FNCP	FNPP
	72	82	100					
1	100	---	---	---	---	---	---	---
2	---	100	---	---	---	---	---	---
3	---	---	100	---	---	---	---	---
4	95	---	---	5	---	---	---	---
5	85	---	---	15	---	---	---	---
6	75	---	---	25	---	---	---	---
7	95	---	---	---	5	---	---	---
8	85	---	---	---	15	---	---	---
9	75	---	---	---	25	---	---	---
10	95	---	---	---	---	5	---	---
11	85	---	---	---	---	15	---	---
12	75	---	---	---	---	25	---	---
13	95	---	---	---	---	---	5	---
14	85	---	---	---	---	---	15	---
15	75	---	---	---	---	---	25	---
16	95	---	---	---	---	---	---	5
17	85	---	---	---	---	---	---	15
18	75	---	---	---	---	---	---	25

* Baker's yeast (1%), sodium chloride (1.5%) and required water were added to each formula
NWB = nano-wheat bran, NWG = nano-wheat germ, FNCP = fermented-nano-carrot pomace, FNPP = fermented-nano- pomegranate peel.

Processing of Egyptian balady bread

According to Yaseen et al. (2007) balady bread was prepared by mixing wheat flour (72% extraction), prepared food by-products, baker's yeast (1%), sodium chloride (1.5%) and water for about 6 min to form the needed dough. The dough was left to ferment for 1h at 30ºC temperature and 85% relative humidity, and then divided into 150g pieces. The pieces were arranged on a wooden board that had been sprinkled with a fine layer of bran and left to ferment for about 45 min at the same temperature and relative humidity. The pieces of fermented dough were flattened to about 20cm in diameter. The flattened loaves were proofed at 30-35ºC and 85% relative humidity for 15min and then baked at 400-500ºC for 1-2min. The loaves of bread were allowed to cool on racks for about 1hr.

Color measurements

The color of balady bread was measured using a spectrocolorimeter with the CIE color scale (Hunter, Lab scan XE) (Commission International de l'Eclairage (CIE), 1976). This instrument was standardized against the white tile of Hunter Lab color standard (LX No.16379): X= 77.26, Y= 81.94 and Z= 88.14. The L*, a* and b* values were reported. Total color difference (ΔE) was calculated as :

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$$

Organoleptic evaluation of Egyptian balady bread

Organoleptic evaluation of balady bread loaves was conducted for the freshly baked breads by 10 semi-trained panelists from the staff (male and female) aged from 25 to 60 years old from Food Industries and Nutrition Division, National Research Centre, Egypt according to El-Farra et al. (1982). The tested characteristics were general appearance (20), separation of layers (20), roundness (15), distribution of crumb (15), crust color (10), taste (10) and odor (10).

Freshness of Egyptian balady bread

Loaves freshness of each packed sample was tested at room temperature (25°C) during storage for 24, 48 and 72 hr by alkaline water retention capacity (AWRC) according to method of Yamazaki (1953), as modified by Kitterman and Rubenthaler (1971). Five grams (W_1) of bread flour was placed into 50 mL dry weighed plastic centrifuge tube (W_2). 25 mL sodium hydrogen carbonate ($NaHCO_3$) solution (8.4g/L) was added. The tube was closed and shaken using vortex shaker to disperse its content, then the mixture was left for 20min. The contents were then centrifuged at 2500 rpm for 15 min. The supernatant was decanted and the precipitate left for 10 min at 45 angles (to get rid of free water) and weighed. The gain in weight was calculated as follow:

$$\frac{(W_3) - (W_1 + W_2)}{W_1} \times 100$$

Loss of freshness (%) was calculated using the following equation:

$$\frac{(AWRC_{\text{zero time}}) - (AWRC_{\text{n time}})}{AWRC_{\text{zero time}}} \times 100$$

Where n= time of storage

Statistical analysis

All samples were analyzed in triplicates and the mean values were expressed. Analysis was assessed using the Statistical Analysis Software for Windows (SAS, 2008). The significant difference between the mean values were determined by using the analysis of variance (ANOVA) and Duncan's multiple range test was conducted at a significance level of $p<0.05$.

Results and Discussion

Transmission Electron Microscopy (TEM)

The TEM images showed that the particle size of WB, WG, RB, CP and PP was distributed in a range of 10-21, 7-19, 15-47, 8-58 and 21-35nm, respectively, which indicated that they are in the nano-scale. The details of these data were previously published in Mohammad et al. (2015).

Organoleptic characteristics of balady bread

Data in Table 2 present the organoleptic characteristics (general appearance, layers separation, roundness, crumb distribution, crust color, taste and odor) of the control and nano and fermented-nano enriched bread samples conducted with 10 panelists. The panelists gave control sample (bread made from wheat flour 72% extraction) the highest scores for all organoleptic characteristics. On contrary, balady bread samples incorporated with FNCP and FNPP at 15 and 25% were scored below acceptability rang. There were no significant differences between the bread samples made from wheat flour 82%, wheat flour 100%, wheat flour incorporated NWB up to 25%, NWG up to 5% and control sample for all measured characteristics. Panelist scores for general appearance were markedly declined with increasing supplementation levels of NWG more than 15%, FNRB more than 5%, as well as FNCP and FNPP at all supplementation levels. The scores of layers separation, roundness and crumb distribution showed the same trend. The increase in fiber contents of bread leads to weakening of gluten network, so its ability to retain the gasses that formed and expanded during oven spring decreased (Schleibinger et al., 2013). Consequently, the layers separation and crumb distribution of these samples were significantly affected. These results are in accordance with those obtained by Seleem and Omran (2014) and Eshak (2016).

Fig. 1. Photographs of balady bread as affected by addition of nano and fermented-nano materials compared with control samples.

NWB = wheat bran; NWG = nano wheat germ; FNRB = fermented-nano rice bran; FNCP = fermented-nano carrot pomace; FNPP = fermented-nano pomegranate peel.

TABLE 2. Organoleptic characteristics of balady bread as affected by addition of nano and fermented-nano materials.

Sample	General appearance (20)	Layers separation (20)	Roundness (15)	Crumb distribution (15)	Crust color (10)	Taste (10)	Odor (10)
Pan bread made from wheat flour extraction (%)							
72	18.8^{A}	19.4^{A}	14.4^{A}	12.2^{AB}	9.2^{A}	9.4^{A}	9.2^{A}
82	16.8^{AB}	17.6^{A}	14.4^{A}	13.2^{AB}	8.2^{AB}	8.6^{AB}	8.4^{ABC}
100	12.0^{CDEFG}	16.4^{AB}	13.4^{ABCD}	11.8^{ABC}	6.8^{ABCD}	7.4^{ABCD}	7.2^{ABCDEF}
Pan bread made from wheat flour 72% incorporated with							
Nano-wheat bran (%)							
5	17.2^{AB}	15.8^{ABC}	13.8^{AB}	14.0^{A}	9.0^{A}	$8.2A^{BC}$	8.2^{ABCD}
15	16.6^{ABC}	17.2^{A}	13.6^{ABC}	12.6^{AB}	9.0^{A}	8.6^{AB}	8.8^{AB}
25	15.4^{ABCD}	16.8^{AB}	13.8^{AB}	12.8^{AB}	8.4^{A}	8.6^{AB}	8.0^{ABCDE}
Nano-wheat germ (%)							
5	15.0^{ABCDE}	16.8^{AB}	13.4^{ABCD}	12.0^{ABC}	7.4^{ABC}	7.8^{ABC}	7.4^{ABCDEF}
15	10.6^{EFGH}	15.6^{ABC}	13.8^{AB}	12.0^{ABC}	5.8^{BCDE}	6.4^{BCDEF}	$7.0^{ABCDEFG}$
25	8.6^{FGH}	12.2^{BCDE}	12.6^{ABCDE}	10.4^{BCDE}	5.0^{CDE}	6.4^{BCDEF}	6.4^{BCDEFG}
Fermented-nano rice bran (%)							
5	13.2^{CDEF}	14.8^{ABCD}	12.2^{ABCDEF}	10.8^{ABCD}	6.8^{ABCD}	6.8^{ABCDE}	6.4^{BCDEFG}
15	9.4^{FGH}	12.2^{BCDE}	10.6^{DEF}	9.8^{BCDE}	5.8^{BCDE}	5.8^{CDEF}	$6.8^{ABCDEFG}$
25	9.4^{FGH}	10.8^{DEF}	10.0^{CEF}	8.6^{CDEF}	4.6^{DE}	4.6^{EFG}	6.4^{BCDEFG}
Fermented-nano carrot pomace (%)							
5	11.4^{DEFGH}	10.6^{DEF}	10.8^{CDEF}	8.6^{CDEF}	5.2^{CDE}	5.8^{CDEF}	6.0^{CDEFG}
15	10.2^{FGH}	11.6^{CDEF}	10.8^{CDEF}	10.0^{BCDE}	4.8^{CDE}	5.0^{DEFG}	6.0^{CDEFG}
25	7.6^{GH}	9.8^{EF}	9.6^{F}	7.8^{DEF}	5.2^{CDE}	4.2^{EFG}	5.6^{DEFG}
Fermented-nano pomegranate peel (%)							
5	$8.4F^{GH}$	10.4^{DEF}	11.0^{BCDEF}	7.2^{EF}	5.8^{BCDE}	4.0^{FG}	5.4^{EFG}
15	7.6^{GH}	8.0^{EF}	11.0^{BCDEF}	6.2^{F}	3.8^{E}	2.6^{G}	4.8^{FG}
25	6.8^{H}	7.2^{F}	10.2^{EF}	6.0^{F}	3.4^{E}	3.0^{G}	4.4^{G}

Values in the same column followed by different letters are significantly different ($p < 0.05$)

It was observed that increasing the level of FNRB, FNCP and FNPP increased the darkness of the prepared bread (Fig. 1). Crust color scores of these samples ranged from 3.4 to 7.4 compared to 9.2 for the bread made from 72% wheat flour. Also, the mean scores of balady bread odor were significantly decreased in these samples as compared to control. Same trend was observed in taste, which showed that addition of NWG or FNRB more than 15% and FNCP or FNPP more than 5% negatively affected the final product in terms of taste and odor (Table 2). Regarding the measured characteristics, the panelists refused breads incorporated 25% FNCP, as well as 15 and 25% FNPP.

Regarding organoleptic evaluation data, mean scores of aroma (taste and flavor) and texture of bread were decreased as the industrial by-products levels increased (Bhol et al., 2016; Belghith et al., 2016b; Stoll et al., 2015 and Wu and Shiau, 2015). However, this effect was not observed in some formulations of wheat bread fortified with some industrial by-products such as brewers spent grain and grape seeds. Moreover, other industrial by-products such as pomegranate bagasses, brewers spent yeast, pumpkin seeds cake and tomato pomace improved the mean scores of some bread characteristics (Majzoobi et al., 2011; Pathak et al., 2016 and Martins et al., 2015).

Color attributes of control and functional balady bread

The color characteristics (L*, a*, b* and ΔE) of both top and bottom layers of balady bread are given in Tables 3 and 4. Data showed that there were no significant differences ($p<0.05$) between the top layer lightness (L* value) of bread samples partially substituted with NWB up to 15% and those made from wheat flour 72 and 82% extraction. Also, there were no significant differences between L* values of the top layer of bread incorporated 25% NWB, 5 and 15% FNRB, 5% NWG, FNCP, FNPP and the crust of whole-meal bread. While, the top layer of bread incorporated NWG, FNCP and FNPP at the levels of 15 and 25% showed significantly lower L* values.

TABLE 3. Color attributes of the top layer of balady bread as affected by addition of nano and fermented-nano materials.

Sample	Lightness (L*)	Redness (a*)	Yellowness (b*)	Total color differences (ΔE)
Balady bread made from wheat flour extraction (%)				
72	75.34^{A}	2.52^{I}	21.73^{H}	0.0
82	68.19^{AB}	3.84^{HI}	22.19^{GH}	6.7^{3IJK}
100	59.96^{BCD}	9.20^{BCDEF}	21.62^{H}	16.21^{FGHI}
Balady bread made from wheat flour 72% incorporated with				
Nano-wheat bran (%)				
5	69.58^{AB}	2.97^{I}	19.95^{I}	5.31^{JK}
15	67.18^{AB}	3.84^{HI}	24.43^{DEF}	8.29^{HIJK}
25	63.00^{BC}	4.64^{GHI}	25.99^{BC}	12.81^{GHIJ}
Nano-wheat germ (%)				
5	60.69^{BC}	8.88^{CDEF}	26.98^{AB}	16.44^{FGHI}
15	47.78^{EFGH}	11.89^{AB}	27.22^{AB}	29.14^{ABCD}
25	40.47^{H}	13.29^{A}	24.86^{CDE}	36.08^{A}
Fermented-nano rice bran (%)				
5	60.48^{BC}	6.65^{FGH}	24.03^{DEF}	15.10^{FGHIJ}
15	55.89^{CDE}	7.00^{EFG}	22.11^{H}	19.36^{DEFG}
25	50.54^{DEFG}	7.98^{DEF}	23.61^{EFG}	24.90^{BCDEF}
Fermented-nano carrot pomace (%)				
5	56.86^{CDE}	6.40^{FGH}	23.00^{FGH}	18.36^{EFGH}
15	49.35^{EFGH}	10.62^{ABCD}	26.29^{ABC}	27.10^{ABCDE}
25	44.83^{FGH}	9.94^{BCDE}	25.17^{CD}	31.10^{ABC}
Fermented-nano pomegranate peel (%)				
5	53.75^{CDEF}	7.63^{EF}	26.99A^{B}	22.32^{CDEFG}
15	47.28^{EFGH}	9.12^{BCDEF}	27.66^{A}	28.93^{ABCD}
25	42.90^{GH}	10.94^{ABC}	27.24^{AB}	33.45^{AB}

Values in the same column followed by different letters are significantly different ($p < 0.05$).

TABLE 4. Color attributes of the bottom layer of balady bread as affected by addition of nano and fermented-nano materials.

Sample	Lightness (L*)	Redness (a*)	Yellowness (b*)	Total color differences (ΔE)
Balady bread made from wheat flour extraction (%)				
72	72.21^{A}	4.60^{GH}	22.92^{B}	0.0
82	66.37^{B}	5.51^{EFG}	22.12^{B}	5.48^{H}
100	59.39^{CD}	7.08^{BCDE}	22.32^{B}	12.44^{DEFG}
Balady bread made from wheat flour 72% incorporated with				
Nano-wheat bran (%)				
5	69.26^{AB}	3.66^{H}	19.09^{EF}	5.41^{H}
15	67.07^{B}	5.50^{EFG}	22.17^{B}	4.82^{H}
25	60.05^{CD}	6.97^{BCDE}	24.95^{A}	11.72^{FG}
Nano-wheat germ (%)				
5	56.80^{DE}	6.26^{CDEF}	19.79^{DE}	15.33^{CDE}
15	54.83^{E}	8.42^{AB}	22.83^{B}	17.10^{C}
25	45.66^{G}	8.79^{A}	21.29^{BCD}	26.29^{A}
Fermented-nano rice bran (%)				
5	62.34^{C}	4.71^{FGH}	19.46^{E}	10.17^{G}
15	56.29^{DE}	6.74^{CDE}	21.74^{BC}	15.49^{CD}
25	56.31^{DE}	6.22^{CDEF}	17.79^{F}	16.50^{C}
Fermented-nano carrot pomace (%)				
5	59.87^{CD}	5.96^{DEFG}	21.75^{BC}	11.89^{EFG}
15	56.76^{DE}	7.62^{ABC}	21.89^{BC}	15.14^{CDEFG}
25	50.42^{F}	7.40^{ABCD}	20.40^{CDE}	21.53^{B}
Fermented-nano pomegranate peel (%)				
5	57.90^{DE}	5.91^{DEFG}	20.08^{DE}	14.25^{CDEF}
15	46.98^{G}	6.98^{BCDE}	20.48^{CDE}	24.86^{A}
25	45.29^{G}	7.65^{ABC}	20.10^{DE}	26.64^{A}

Values in the same column followed by different letters are significantly different ($p < 0.05$)

As can be seen in Table 3, the lowest L* value (40.47) was recorded to the top layer of bread containing 25% NWG compared to 75.34 and 59.96 for the top layer of bread made from wheat flour 72 and 100%, respectively. The darkness of bread containing NWG could be due to Millard reaction, while the darkness of bread containing FNCP and FNPP could be due to the dark color of the added powder itself. The same trend was also noticed when L* values of the bottom layer were considered.

Redness (a*) values of the top and bottom layers of balady bread showed opposite trend to L* values. Bread samples incorporated 15 and 25% NWG, FNCP and FNPP had significantly higher a* values compared to other samples Tables (2 and 3). There were no significant differences between a* values of the top layer of bread made from wheat flour 72 and 82% and those containing NWB at all levels being 2.52, 3.84, 2.97, 3.84 and 4.64, respectively. As mentioned above, the brown color of top layer is known to be the result of Maillard reaction, thus high protein content could promote the occurrence of Maillard reaction (Gomez et al., 2003). So, addition of NWG significantly increased a* value. The highest a* value was recorded to bread incorporated 25% NWG being 13.29 and 8.79 for the top and bottom layers, respectively. The high a* values of bread containing NWG could be to its high protein content.

Yellowness (b*) value of both top and bottom layers of balady bread were significantly different and showed different trends. The top layer of bread samples containing NWG, FNCP and FNPP showed higher b* values compared to other samples Tables (3 and 4). While, b* values of the bottom layer of bread made from wheat flour 72, 82, 100% and wheat flour incorporated NWB up to 25% were significantly higher compared to other samples. The higher b* values of top layers of balady bread samples compared to the bottom layers could be due to the baking method, where the top layer directly faces the oven fire. The top layer of bread sample incorporated 15% FNPP showed the highest b* being 27.66, while the lowest b* value was recorded to the top layer of bread incorporated 5% NWB, 19.95. But the bottom layer of bread incorporated 25% NWB showed the highest b* value, 24.95, while the lowest value was recorded to the bottom layer of bread containing 25% FNRB being 17.79.

Regarding total color differences (ΔE), the top layer color of bread samples made from wheat flour 82% and those containing NWB up to 15% was more homogenous compared to control sample. On contrary, the top layer color of bread samples containing NWG, FNCP and FNPP showed asymmetry color properties (Table 2). Generally, it could be concluded that NWB up to 25% was more suitable to produce high fiber balady bread with low ΔE value compared to bread made from wheat flour 72%. The lowest ΔE value was recorded to the top layer of the sample containing 5% NWB, 5.31, while the highest value was recorded to the sample containing 25% NWG being 36.08. The same trend was observed when ΔE values of the bottom layer of bread were considered.

Decreased lightness (L* value) in bread fortified with potential functional ingredients from industrial by-products was frequently noticed (Belghith et al., 2016a; Shiau et al., 2015; Martins et al., 2015 and Martins et al., 2017). Maillard and caramelization reactions are usually the major reasons of the darker color quality of processed food products, but the native color of utilized by-products also influenced the color quality of the final products (Juszczak et al., 2012; Peressini and Sensidoni, 2009 and Martins et al., 2017).

Freshness properties of balady bread as affected by addition of nano and fermented-nano-materials

Results in Table 5 showed that there was a gradual decrease in swelling power of all balady bread samples after baking. The control bread showed significantly higher AWRC values at zero time (306.11%) and during 24 (254.18%) and 48 h (194.84%), but after 72 h bread sample containing 5% FNRB showed the highest AWRC value being 159.96% compared to 150.33% for the control sample. While, balady bread made from whole-meal flour showed the lowest AWRC values during storage time (140.19, 106.72 and 81.62% at 24, 48 and 72 hr, respectively). Also, data presented in this table showed significant negative effects of adding fiber materials on the swelling power of balady bread samples at zero time compared to control sample. The highest negative effect was recorded for FNPP at the level of 25% (160.94%).

Figure 2 shows that addition of nano and fermented-nano materials retarded the staling of balady bread samples during storage period (72 hr) at room temperature. Balady bread manufactured using wheat flour 72% and whole-meal flour had faster staling rate. They loosed their freshness at the rate of 16.96 and 17.28%, 36.35 and 37.03% and 50.89 and 51.83% after 24, 48 and 72 hr, respectively. While, balady bread containing 25% FNCP had the lowest staling rate as it loosed only 8.63, 18.49 and 25.89% from its original freshness after 24, 48 and 72 hr, respectively. Also, bread samples containing 25% NWG, 15% FNRB and 15% FNPP had low staling rate. For instance, these samples lost 35.12, 34.05 and 31.37% from their original freshness after 72 hr, respectively.

Also, a reversed relationship between the staling rate and the level of addition was observed in all tested materials except FNRB. Addition of FNRB at 25% increased the staling rate of produced bread being 41.8% after 72hr of storage compared to 34.05% for bread containing 15% FNRB after the same time. The obtained results are in accordance with the results of Feili et al. (2013) who attributed this effect to the fiber capability of water binding and the potential interaction between fiber and starch. Under these conditions, water loss and starch retrogradation during storage are delayed.

Conclusion

From the obtained results it could be concluded that, functional Egyptian balady bread with acceptable quality could be prepared using wheat flour replaced by NWB or NWG up to 25% or FNRP up to 15 %, FNCP or FNPP up to 5 %.

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TABLE 5. Alkaline water retention capacity of balady bread as affected by addition of nano and fermented-nano materials (%).

Sample	Storage time (h)			
	Zero	24	48	72
Balady bread made from wheat flour extraction (%)				
72	306.11^{A}	254.18^{A}	194.84^{A}	150.33^{B}
82	237.90^{E}	201.06^{F}	158.94^{G}	127.36^{HI}
100	169.47^{N}	140.19^{L}	106.72^{M}	81.62^{L}
Balady bread made from wheat flour 82% incorporated with				
Nano-wheat bran (%)				
5	260.08^{B}	219.59^{C}	173.31^{D}	138.61^{CD}
15	234.51^{F}	205.47^{E}	172.28^{D}	147.39^{B}
25	200.26^{KL}	176.17^{J}	148.64^{J}	127.99^{GHI}
Nano-wheat germ (%)				
5	226.72^{H}	193.16^{HI}	154.81^{H}	126.05^{I}
15	243.43^{D}	212.46^{D}	177.06^{C}	150.51^{B}
25	202.20^{K}	178.53^{J}	151.48^{I}	131.19^{FG}
Fermented-nano rice bran (%)				
5	253.73^{C}	222.47^{B}	186.75^{B}	159.96^{A}
15	227.57^{H}	201.75^{F}	172.23^{D}	150.09^{B}
25	230.58^{G}	198.46^{G}	161.75^{F}	134.21^{EF}
Fermented-nano carrot pomace (%)				
5	221.54^{I}	190.99^{I}	156.08^{H}	129.89^{GH}
15	205.17^{J}	177.07^{J}	144.96^{K}	120.88^{J}
25	188.07^{M}	171.84^{K}	153.29^{HI}	139.38^{CD}
Fermented-nano pomegranate peel (%)				
5	221.27^{I}	194.89^{H}	164.73^{E}	142.11^{C}
15	198.50^{L}	177.74^{J}	154.02^{HI}	136.23^{DE}
25	160.94^{O}	141.69^{L}	119.70^{L}	103.20^{K}

Values in the same column followed by different letters are significantly different ($p < 0.05$) **.**

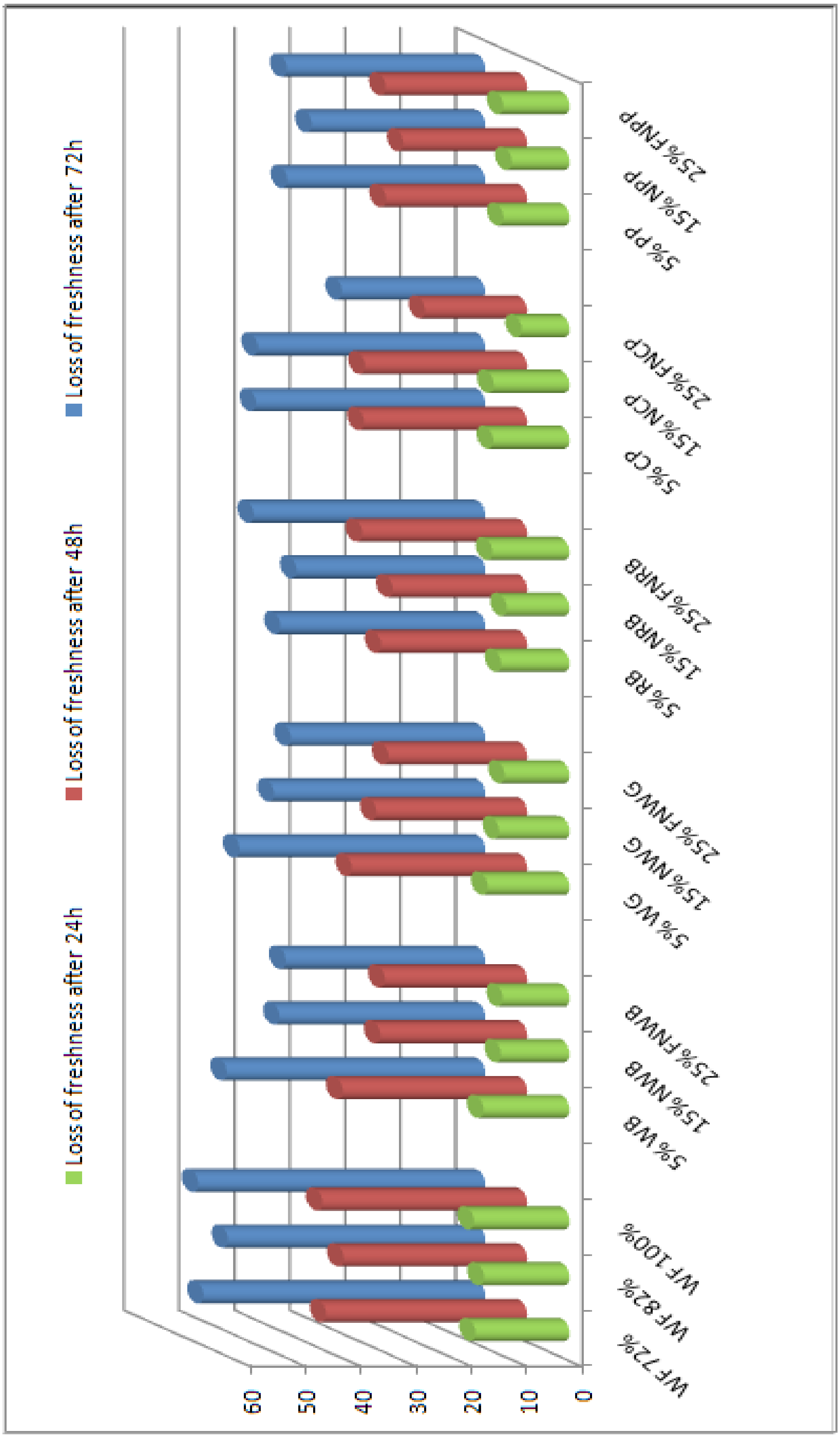

Fig. 2. Loss of freshness in balady bread during storage as affected by addition of nano and fermented-nano materials

WF = wheat flour, NWB = nano-wheat bran, NWG = nano-wheat germ, FNCP = fermented-nano-carrot pomace, FNPP = fermented-nano- pomegranate peel.

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تأثير المساحيق النانومترية لبعض النواتج الثانوية للتصنيع الغذائي على جودة الخبز البلدي المصري

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تعتبر تكنولوجيا النانو من التكنولوجيات الواعدة في تطوير طرق التصنيع الغذائي التقليدية، حيث يعتبر تحويل المواد الغذائية الى الصورة النانومترية من الطرق المتطورة التي تستخدم في تحرير المركبات الفعالة بها وكذلك زيادة الاتاحة الحيوية لهذة المركبات وبالتالي يمكن استخدامها كمدعمات غذائية. في هذه الدراسة، تم استخدام خمسة نواتج ثانوية للتصنيع الغذائي هي ردة القمح وجنين القمح في الصورة النانومترية وردة الارز والياف الجزر وقشور الرمان في الصورة النانومترية المتخمرة كمصادر طبيعية للمركبات ذات النشاط الحيوي في تدعيم الخبز البلدي المصري. وقد تم اضافة هذه المواد الى دقيق القمح بثلاث مستويات من الاحلال هي ٥، ١٥ و٢٥٪ واستخدام هده الخلطات في تصنيع الخبز البلدي وتقييم الخواص الحسية وخواص التجلد بالاضافة الى عناصر اللون (L^*, a^*, b^*, ΔE) للخبز الناتج. اوضحت نتائج اختبار القدرة على ربط الماء القلوي كاحد مقاييس تجلد الخبز ان جميع المواد المدروسة كان لها تاثير ايجابي في تاخير ظاهرة البيات في الخبز خلال فترة تخزينه لمدة ٧٢ ساعة على درجة حرارة الغرفة مقارنة بعينة الكنترول. كذلك اوضحت خصائص اللون لكل من الطبقة العليا والسفلى وجود اختلافات معنوية بين عينة الكنترول والعينات المدعمة وكانت هذه النتائج متوافقة مع نتائج الاختبارات الحسية التي اوضحت امكانية تدعيم الخبز البلدي بكل من ردة القمح وجنين القمح في الصورة النانومترية حتى نسبة احلال ٢٥٪، وردة الارز النانومترية المتخمرة حتى نسبة ١٥٪، في حين ان الياف الجزر وقشور الرمان النانومترية المتخمرة لا يمكن اضافتها بنسبة اكبر من ٥٪ حفاظا على خواص جودة الخبز الناتج.