



## Physico-Chemical and Organolytical Characteristics Of Cake Fortified By Irradiated Broccoli (*Brassica Oleracea L.Var Italica*) Powder

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### ABSTRACT

The present study aims to improve the antioxidant and antimicrobial properties of cake and produce low calorie cake through substitution of wheat flour (WF) by irradiated broccoli (*Brassica oleracea L.var italica*) powder. In this study broccoli heads powder and broccoli leaves powder were gamma irradiated at dose levels of 0, 3, 5 and 7 kGy. Results showed that ethanolic (70%) extract of irradiated broccoli heads powder (IBHP) and irradiated broccoli leaves powder (IBLP) at a dose level of 5 kGy had higher total phenolic compounds (TPC) and antioxidant activity (AOA) compared to control and other doses. Thus, IBHP and IBLP at dose level of 5 kGy were selected for fortification of cake. IBHP was used to substitute (0, 1.5, 3, and 4.5 %) of WF in making cake, as well, replacement of WF (0, 1, 2 and 3%) by IBLP. The results showed that the cake processed from IBHP and IBLP had pronounced improvement (%) in its chemical composition (protein, lipids, ash and fiber content) while, the energy value and carbohydrate content decreased with increasing the replacement level. Also, the results showed that the TPC content, AOA, volume and specific volume were increased by increasing substitution level of IBHP and IBLP compared to control samples. On the other hand, total intensity, L\* and a\* values of the crust and crumb were decreased, whereas Chroma and b\* values were increased for crumb and decreased for crust for all cake treatments by the addition of IBHP and IBLP compared to control sample. For microbiological properties, the results

### KEYWORDS

*Broccoli Heads Powder, Broccoli Leaves Powder, Low Caloric Cake, Replacement, Total Phenolic Compounds, Antioxidant, Physical Properties, Sensory Properties.*

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showed that, increasing of IBHP and IBLP substitution level decreased the microbial count compared to control samples. Finally, the results showed that the sensory characteristics liking results pointed out that a partial replacement of cake flour with less than or equal to (3 and 2%) IBHP and IBLP, respectively in cake is satisfactory..

## INTRODUCTION

**B**roccoli, (*Brassica oleracea* L.var. *italica*), belongs to the family Brassicaceae or Cruciferae (commonly known as the mustard family), genus *Brassica* and species *oleracea* (Dixon, 2007; Higdon et al., 2007; Perera et al., 2007; Podsdek, 2007; Jahangir et al., 2009). It is a popular vegetable and healthy horticultural produce with a high nutritional value, due to its significant content of carbohydrates, protein, carotenoids, dietary fiber, niacin and an excellent source of vitamins (C, A and E), folate, antioxidants, anticarcinogenic compounds (such as glucosinolates) and health-promoting phytochemicals (Yuan et al., 2010). It also contains good levels of calcium, iron and potassium (Gourley, 2003; Lister and Bradstock, 2003; Zhang and Hamazu, 2004).

Moreover broccoli is a rich source of phytochemicals (phenolic Compounds and glucosinolates), Phenolic compounds are known to be the major antioxidants of Brassica crops (Podsdek, 2007). Phenolic compounds have also been reported to act as antimicrobials against pathogenic gram-positive and gram-negative bacteria such as *Staphylococcus aureus*, *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella Typhimurium* (Caillet et al., 2012), often contamination foods with these bacteria (Gombelli et al., 2015; Maffei et al., 2016).

There are many varieties of green leafy vegetables which are rich in micronutrients, but are usually discarded or not used for human consumption. Broccoli leaves is one of them, which is available at

no cost and is rich in all the macronutrient. It is an exceptionally nutritious vegetable with a variety of potential uses. According to FAO, The leaves contribute about 50% of the total production of broccoli. In the field, up to 70% of the total weight of the broccoli plant is discarded, generating high quantities of florets, leaves and stalks as crop remains. These materials are often regarded as crop remains and a small percentage is used without treatment in animal feed. Recently, recovery and bioconversion of vegetables residues to high-value compounds has been receiving great attention (Mahro and Timm, 2007). USDA (2011) reported the nutritional value of broccoli leaves as calories 28 kcal, protein 3 g, calcium 48g, iron 0.88mg, vitamin A 16000IU, vitamin C 93.2 mg. They also reported that this food is low in saturated fatty acids, and very low in cholesterol. It is also a good source of protein, thiamin, niacin, pantothenic acid, calcium, iron, and selenium and a very good source of vitamin A, Vitamin C, riboflavin, vitamin B6, folate, magnesium, phosphorus, potassium and manganese.

The use of fruit and vegetable by-products as natural food additives has recently been suggested, due to their high content of polyphenols, carotenoids, dietary fiber, or other bioactive compounds (Blasa et al., 2010; Galanakis et al., 2010; O'Shea et al., 2012; Al-Sayed and Ahmed, 2013).

On the other hand, the content of plant antioxidants and its activity were reported to increase by gamma irradiation (Variyar et al., 1998; Alothman et al., 2009). In this concern, gamma irradiation was applied at various doses to date palm fruit Mazafati, where the amount of total phenolic and antioxidant activity were increased significantly (Ghadi et al., 2015). Also, (Sima et al., 2014) noticed that methanol extract of *Curcuma alismatifolia* leaves increased total phenolic and antioxidant activity by gamma irradiation.

Bakery products are widely consumed and are becoming a major component of the international

food market (Kotsianis *et al.*, 2002). Cake is one of the most popular bakery items consumed in the world because of nutritional value, different varieties and affordable price. Lipid oxidation and mold growth are major problems in producing cake, which limits shelf-life of this product. The onset rancidity in bakery products causes a great influence on texture, color and organoleptic parameters, also losses the nutritional value (Sabouri *et al.*, 2012). These problems may be prevented by the use of antioxidants and preservatives (Khaki *et al.*, 2012).

Antioxidants are used as food additives in order to prevent the oxidative deterioration of fats and oils in processed food. There is a great interest nowadays for the use of new natural antioxidants in food, especially in bakery products instead of synthetic antioxidants (Nanditha and Prabhasankar, 2009).

Cake is usually made from soft WF at higher extraction caused deficient in fibers and phytochemicals. On the other hand, the demand for health-oriented products that have high fiber, natural antioxidants, and low calorie contents is increasing because of their beneficial health effects (Rodríguez *et al.*, 2006; Patsioura *et al.*, 2011). Recently, alternative fibers from different sources are available which may provide fibers and phytochemicals as natural components, like fruit, vegetable and their residues (Rodríguez *et al.*, 2006). Broccoli heads and leaves are good sources of natural antioxidants, antimicrobial, phenolic compounds and fibers. Many epidemiological studies assert that fibers consumption helps to reduce obesity, some cancer kinds and cardiovascular diseases. Therefore, the fibers consumption recommended being up to 20 - 35 g daily. Newly, some researches were mentioned that food residues could be incorporated into cake making such as carrot leafs (Santos *et al.*, 2014), watermelon rinds and sharlyn melon peels powders (Al-Sayed and Ahmed, 2013), potato peels (Kaack and Pedersen, 2005; Dhingra *et al.*, 2012), flaxseeds (Moraes *et al.*, 2010) and apple pomace (Masoodi *et al.*, 2002;

Sudha *et al.*, 2007). Indeed, incorporating the broccoli head and leaf powders could increase its added-value, decrease the cake total manufacturing cost and provide phytochemicals, antioxidants into the human diets.

The aim objective of this study were to determine the effect of the partial replacement of WF by both irradiated dried broccoli heads and leaves powder in cake making to produce low caloric cake, and study the effect of this replacement on chemical composition, antioxidant activity, phenolic compound content, physical, microbiological and organoleptic characteristics of cake during storage at room temperature.

## MATERIALS AND METHODS

### Materials:

#### Plant samples:

Fresh whole broccoli (*Brassica oleracea L.*) was obtained from the farm of agricultural research center on the same day of harvest. Broccoli was separated into two parts: the first part was the heads (flower and portion of stem); the second part was the leaves.

#### Ingredients of cake:

Wheat Flour (72% extraction) was purchased from Algamal flour mills in 6 October city.

Sugar, milk, eggs, fat, baking powder and vanilla were purchased from supermarket, Cairo, Egypt.

#### Chemicals:

2,2-Diphenyl-1-picrylhydrazyl (DPPH), gallic acid, Folin-Ciocalteu reagent, were produced by Sigma Chemical Co. (St. Louis, MO, USA). All other used chemicals were analytical grade. All chemicals, reagents and medium (nutrient agar, MacConkey agar, Salmonella Shigella agar and Potato-dextrose agar) of the analytical methods used in present study were purchased from EL.Gamhouria Trading Chemicals and Drugs Co. (Egypt).

**Methods:****Preparation and irradiation of broccoli heads and leaves samples:**

Both of two separated parts (heads and leaves) were rinsed by distilled water, the plant parts were cut into small slices in order to facilitate the drying process, then dried in oven at 45°C for 72 h then ground to a fine powder in a coffee grinder for 2 min, and passed through a 60 mesh sieve to obtain fine homogenous powder. The dried samples were packed in eight packages each containing 200g which irradiated to doses of 0, 3, 5 and 7 KGy, individually, using a <sup>60</sup>Co Russian gamma chamber (dose rate 0.98KGy/h) belonging to Cyclotron Project, Nuclear Research Center, Atomic Energy Authority, Cairo, Egypt.

**Preparation of broccoli heads and leaves extracts:**

Samples of non-irradiated and irradiated dry heads and leaves powder (10 gm) at dose level of 3, 5 and 7 kGy were soaked individually into 100 ml ethanol 70%. All samples were shaken at room temperature for 7-8h at a speed of 1000 vibration/min. Then were filtered through Whatman filter paper No.1 and the residue was resoaked again in 100 ml of respective solvent to ensure the complete extraction. Filtrate (extract) was subjected to rotary evaporator at 45°C under reduced pressure to remove solvent and concentrate to 10 ml. The obtained extracts were stored at -18 °C in brown bottles to further analyses.

**Total Phenolic Compounds and Antioxidant Activity:****Total phenolic compounds:**

Total phenolic compounds content was determined by the Folin–Ciocalteu method according to (Arabshahi-Delouee and Urooj, 2007). A 200 µL of each extract solution was mixed with 1 mL of Folin–Ciocalteu's reagent (1 ml reagent with 9 ml distilled water) after 5 min add 1.5mL distilled water and 1mL of 75 g L<sup>-1</sup> Na<sub>2</sub>CO<sub>3</sub> solution. The mixture was incu-

bated in a shaking incubator at ambient temperature for 60 min and its absorbance at 760 nm was measured. Gallic acid was used as a standard for the calibration curve (correlation coefficient “R<sup>2</sup>”= 0.9944). Total phenolic content expressed as gallic acid equivalent (GAE) was calculated using the following linear equation based on the calibration curve:

$$Y = 0.0045 X + 0.0743$$

Where:

Y: is the absorbance.

X: is the concentration (mg GAE g<sup>-1</sup> extract).

**Determination of antioxidant activity:**

The antioxidant activity (AOA) was determined using DPPH assay according to (Hanato *et al.*, 1988) with minor modification. A 0.1 ml of each extract was vortexed for 30s with 3.9 ml of 0.1 mM DPPH• solution and left to react for 30 min at room temperature, afterword the absorbance was determined against a control at 517 nm (Gulcin *et al.*, 2004). Percentage of antioxidant activity of free radical DPPH was calculated as follows:

Antioxidant activity (Inhibition) % =

$$[(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}}] \times 100$$

Where: A<sub>control</sub> is the absorbance of the control reaction and A<sub>sample</sub> is the absorbance in the presence of sample extract.

**Preparation of cake samples:**

Cakes were prepared according to the method described by (Lu *et al.*, 2010) using the following formula: 1000 g WF (72% extraction) without antioxidants, 850 g sugar, 50 g shortening, 40 g baking powder, 250g eggs, 200 ml milk and 17 g vanilla. The ingredients were mixed for 3-4 minutes and placed on aluminum cups then backed in an oven at 180°C ± 5°C for 30 - 35 min, after achieving the following treatments. Cakes were prepared to provide seven samples: The first sample without treatment (con-

trol). The second sample was prepared by replacing WF by 1.5% irradiated broccoli heads powder (IBHP) While, the other samples were prepared by replacing WF by 3% and 4.5% IBHP, 1% , 2% and 3% irradiated broccoli leaves powder (IBLP). Cake samples were stored at room temperature ( $25^{\circ}\text{C} \pm 2$ ) for 18 days.

#### Approximate Chemical Composition:

Moisture, ash, protein, fat and crude fiber of all cake samples, IBHP and IBLP samples were determined according to the methods described in (A.O.A.C., 2012). The carbohydrate was calculated by difference as follows:

Total carbohydrate =  $100 - (\% \text{moisture} + \% \text{protein} + \% \text{fat} + \% \text{ash} + \% \text{fiber})$ . To calculate the food energy value, the main components were converted using conversion factors as (4.0 kcal/g) for proteins and available carbohydrates, (9.0 kcal/g) for fats, according to (FAO, 2003).

#### Physical analyses of cake:

##### Determination of weight, volume and specific volume for cake samples:

Cake mass was weighted after 3 hours at room temperature. The volume ( $\text{cm}^3$ ) was measured by replacement method described in the (A.A.C.C., 1983). The specific volume was obtained by dividing the volume of cakes by their weights.

##### Determination of cake color samples:

Crumb and crust color of fresh cake was measured with a Hunter lab DP 9000 D 52L optical sensor using  $L^*$ ,  $a^*$  and  $b^*$  color scale. The instrument was standardized each time with a white and black ceramic plate. The samples were scanned at five different locations and the mean values of  $L$ ,  $a$ ,  $b$  were recorded. The total color change ( $\Delta E$ ) of each cake was calculated as described by (Mai *et al.*, 2007) as follows  $\Delta E = [(L^* - L)^2 + (a^* - a)^2 + (b^* - b)^2]^{1/2}$ . Where  $L^*$ ,  $a^*$  and  $b^*$  are the lightness, redness and yellow-

ness color score respectively at time zero. The  $L$ ,  $a$ , and  $b$  represented the instantaneous individual reading. The Chroma ( $C$ ) represents color saturation or purity was calculated from  $C = (a^2 + b^2)^{1/2}$  and total color intensity =  $(a^2 + b^2 + L^2)^{1/2}$ .

#### Microbiological analyses of cake:

##### Bacteriological Methods:

##### Total plate bacterial count:

The total plate bacterial counts were determined using the plate counts technique on a nutrient agar medium according to the procedures described in (APHA, 1992). The plates were incubated at  $37^{\circ}\text{C}$  for 48 hrs.

##### Coliform bacterial count:

The coliform bacteria were determined using MacConkey agar medium according to the procedures described in (APHA, 1992). The plates were incubated at  $37^{\circ}\text{C}$  for 24 hrs.

##### Detection of salmonella:

The presence or absence of Salmonella was determined according to the method described by (FAO, 1979). Salmonella Shigella agar plates were incubated at  $35^{\circ}\text{C}$  for 24 h. Salmonella appeared as black colonies, some of them with metallic sheet.

##### Molds and Yeasts methods:

The procedures of (APHA, 1992) were followed for the determination of mold and yeast counts using potato-dextrose agar medium. The plates were incubated at  $20 - 25^{\circ}\text{C}$  for 5 days.

##### Sensory properties of cake samples:

All cake samples were periodically examined (every 6 days) by ten panelists from the staff members of Food irradiation unit, Plant Research Department, Nuclear Research Center. Panelists were asked to score the quality attributes of each cake sample. Appearance, crust color, crumb color, taste, odor and

overall acceptability were judged on a scale of 10 according to (A.A.C.C., 1996).

#### Statistical Analysis:

The data obtained from three replicates were analyzed by (ANOVA) using the SPSS statistical package program, and differences among the means were compared using the

Duncan's Multiple Range test SPSS (1998). A significant level of 0.05 was chosen.

## RESULTS AND DISCUSSION

### *Effect of gamma irradiation on total phenolic content (TPC) and antioxidant activity (AOA) of broccoli heads and leaves extracts:*

Data in **Table (1)** shows that different dose levels (3, 5 and 7 kGy) increased the TPC content and the DPPH radical scavenging activities in both heads and leaves powders compared to non-irradiated sample.

**Table (1) :** Total phenolic and DPPH radical scavenging activity of the non-irradiated and irradiated broccoli heads and leaves powder extracts.

Doses	Samples			
	Broccoli heads powder		Broccoli leaves powder	
	TPC (mg GAE/ 100g )	DPPH%	TPC (mg GAE/ 100g )	DPPH%
0 kGY	916.55 <sup>c</sup> ±2.13	78.84 <sup>b</sup> ±0.47	1187.68 <sup>b</sup> ±2.10	88.23 <sup>b</sup> ±0.12
3 kGY	921.64 <sup>c</sup> ±2.90	81.33 <sup>a</sup> ±0.30	1205.04 <sup>b</sup> ±1.86	88.59 <sup>b</sup> ±0.15
5 kGY	1132.75 <sup>a</sup> ±2.68	82.33 <sup>a</sup> ±0.32	1299.26 <sup>a</sup> ±2.47	89.87 <sup>a</sup> ±0.29
7 kGY	980.97 <sup>b</sup> ±2.12	81.42 <sup>a</sup> ±0.24	1286.01 <sup>a</sup> ±1.92	88.75 <sup>b</sup> ±0.24

(Means ± SE).

A.B.C: Means with the same letter in the same column are not significantly different ( $p > 0.05$ )

The ethanolic 70% extract of irradiated heads at dose level of 5kGy has a clear significant ( $p < 0.05$ ) increase in TPC contents and the DPPH radical scavenging activities as compared to that of the control sample and other doses, which it were 916.55 mg GAE/100g DW and 78.84%, respectively in control and increased to 1132.75 mg GAE/100g DW and 82.33%, respectively after irradiation treatment.

In the case of leaves, as also shown in **Table (1)** the irradiation treatment had the same manner of acting for TPC contents and DPPH radical scavenging activities of IBHP.

Generally the different dose levels increased the content of TPC and enhanced the DPPH scavenging activity of the ethanol 70% extracts of the samples compared to non-irradiated sample. The ethanolic 70% extract of irradiated leaves at dose level of

5kGy recorded the highest values of TPC content and DPPH radical scavenging activities being 1299.26 mg GAE/100g DW and 89.87%, respectively. While the non-irradiated sample recorded the lowest values of TPC content and DPPH radical scavenging activities.

The results showed that ethanolic 70% extract of irradiated broccoli heads powder (IBHP) and irradiated broccoli leaves powder (IBLP) at a dose level of 5 kGy extract had higher total phenolic compounds (TPC) and antioxidant activity (AOA) compared to other doses. Thus, IBHP and IBLP at dose level of 5 kGy were selected to add in cake making.

### *Chemical composition of wheat flour (WF), irradiated broccoli heads (IBHP) and irradiated broccoli leaves (IBLP) powder at dose level of 5 kGy:*

The proximate chemical composition of WF, IBHP and IBLP are present in **Table (2)**.

**Table (2) :** Chemical composition of WF, IBHP and IBLP at dose level of 5 kGy.

Components	WF 72%	IBHP	IBLP
Moisture (%)	13.22 <sup>A</sup> ±0.13	10.59 <sup>B</sup> ±0.14	9.33 <sup>C</sup> ±0.17
Crude protein (%)	15.19 <sup>B</sup> ±0.16	19.84 <sup>A</sup> ±0.09	15.84 <sup>C</sup> ±0.12
Ether extract (%)	1.74 <sup>B</sup> ±0.034	3.71 <sup>B</sup> ±0.04	4.04 <sup>A</sup> ±0.05
Ash (%)	0.88 <sup>C</sup> ±0.04	7.32 <sup>B</sup> ±0.07	13.96 <sup>A</sup> ±0.08
Crude fiber (%)	0.58 <sup>C</sup> ±0.025	10.38 <sup>A</sup> ±0.09	9.76 <sup>B</sup> ±0.09
Carbohydrates* (%)	68.39 <sup>A</sup> ±0.21	48.16 <sup>B</sup> ±0.13	47.07 <sup>C</sup> ±0.05
Energy value (kcal 100 g <sup>-1</sup> )	349.98 <sup>A</sup> ±0.45	305.39 <sup>B</sup> ±1.2	288 <sup>C</sup> ±0.78

(Means ± SE).

A.B.C: Means with the same letter in the same raw are not significantly different ( $p > 0.05$ ).

\*Total carbohydrate was calculated by difference.

From statistical analysis of these data it could be noticed that a significant differences ( $p < 0.05$ ) were recorded in the gross chemical composition between all the tested raw materials. The obtained results revealed that WF recorded the highest moisture content being 13.22%, while IBHP and IBLP had lower moisture content being 10.59 and 9.33%, respectively.

On the other hand, IBHP had the highest crude protein and crude fiber content being 19.84 and 10.38%, respectively, followed by IBLP where they were 15.84 and 9.76%, respectively. IBLP had the highest ether extract and ash content being 4.04 and 13.96% respectively, followed by IBHP 3.71 and 7.32%, respectively. While WF had the lowest value of crude protein, ether extract, ash and crude fiber content being 15.19, 1.74, 0.88 and 0.58%, respectively. WF recorded the highest values of carbohydrate being 68.39%, followed by IBHP being 48.16%. Meanwhile, IBLP had the lowest carbohydrate 47.07%. Also, WF recorded the highest energy values being 349.98 kcal 100 g<sup>-1</sup>, followed by IBHP being 305.39 kcal 100 g<sup>-1</sup>, while IBLP had the lowest energy values 288 kcal 100 g<sup>-1</sup>. These results are nearly close to the results obtained by (Ali and Halim, 2013; Sankhon *et al.*, 2013; Madhu and Kochhar, 2014). The difference in chemical composition is due to the variation in the environmental con-

ditions, mainly temperature, soil fertility, agronomic practices such as irrigation, fertilization, harvest and the maturity stage of broccoli and wheat plants.

#### **Chemical composition of cake fortified by IBHP and IBLP at dose level of 5 kGy:**

Proximate chemical analysis of WF cake, cake fortified by with 1.5, 3 and 4.5% of IBHP; 1, 2 and 3% for IBLP are tabulated in **Table (3)**. From these results it could be observed that, there were significant differences ( $p < 0.05$ ) in ash and crud fiber contents between all fortified cake treatments and control cake sample. On the other hand, there were no significant differences ( $p > 0.05$ ) in moisture, protein, ether extract, carbohydrate and energy values for fortified cake samples compared with control.

Data in **Table (3)** showed that, protein and ether extract contents from different fortified cake samples were increased as the percentage of IBHP and IBLP increase, but no significant different between all samples treatment and control sample, Also ash and fiber contents of cake samples were increased as increasing the replacement level of WF by IBHP and IBLP with Significant deferent between control and some sample treatment. In the same time, carbohydrate and energy value were decreased as the level of replacement increased, but no significant different between all samples treatment and control sample

except for IBHP and IBLP powder at 4.5 and 3 concentrate respectively. These results are in agreement with (Menon *et al.*, 2014; Prokopov *et al.*, 2015).

Generally, it could be seen that cake processed from the investigated IBHP and IBLP had pro-

nounced improvement % in its chemical composition (protein, lipids, ash and fiber content) excepted the energy value and carbohydrate content decreased with increasing the replacement level, which means the possibility of producing a cake with high nutritional value and low caloric.

**Table (3) :** Chemical composition of different cake treatment as affected by IBHP and IBLP at dose level of 5 kGy.

Characteristics	Control	Treatments					
		IBHP			IBLP		
		1.5%	3%	4.5%	1%	2%	3%
Moisture (%)	26.7 <sup>A</sup> ±0.38	26.69 <sup>A</sup> ±0.35	26.82 <sup>A</sup> ±0.36	26.39 <sup>A</sup> ±0.53	26.71 <sup>A</sup> ±0.74	26.68 <sup>A</sup> ±0.70	26.59 <sup>A</sup> ±1.01
Protein (%)	12.73 <sup>A</sup> ±0.13	12.77 <sup>A</sup> ±0.20	12.82 <sup>A</sup> ±0.20	12.85 <sup>A</sup> ±0.45	12.72 <sup>A</sup> ±0.19	12.76 <sup>A</sup> ±0.13	12.79 <sup>A</sup> ±0.15
Ether extract (%)	9.69 <sup>A</sup> ±0.10	9.71 <sup>A</sup> ±0.14	9.76 <sup>A</sup> ±0.11	9.79 <sup>A</sup> ±0.19	9.72 <sup>A</sup> ±0.18	9.75 <sup>A</sup> ±0.15	9.78 <sup>A</sup> ±0.17
Ash (%)	1.53 <sup>P</sup> ±0.08	1.75 <sup>CD</sup> ±0.05	1.95 <sup>ABCD</sup> ±0.12	2.29 <sup>AB</sup> ±0.17	1.89 <sup>BCD</sup> ±0.12	2.12 <sup>ABC</sup> ±0.13	2.36 <sup>A</sup> ±0.19
Fiber (%)	0.81 <sup>C</sup> ±0.06	1.14 <sup>B</sup> ±0.10	1.34 <sup>AB</sup> ±0.09	1.58 <sup>A</sup> ±0.17	1.15 <sup>B</sup> ±0.08	1.24 <sup>B</sup> ±0.07	1.32 <sup>AB</sup> ±0.05
Carbohydrate* (%)	48.49 <sup>A</sup> ±0.16	47.94 <sup>A</sup> ±0.22	47.31 <sup>AB</sup> ±0.19	47.10 <sup>B</sup> ±0.20	47.81 <sup>A</sup> ±0.14	47.45 <sup>AB</sup> ±0.28	47.16 <sup>B</sup> ±0.42
Energy value (kcal 100 g <sup>-1</sup> )	332.29 <sup>A</sup> ±1.8	330.23 <sup>AB</sup> ±1.4	328.36 <sup>AB</sup> ±2.1	327.91 <sup>B</sup> ±2.6	329.73 <sup>AB</sup> ±2.9	328.59 <sup>AB</sup> ±2.7	327.82 <sup>B</sup> ±2.5

(Means ± SE).

A.B.C: Means with the same letter in the same raw are not significantly different ( $p > 0.05$ ).

\* Total carbohydrate was calculated by difference.

### Physical analyses of cake:

#### Determination of weight, volume and specific volume for fresh cake prepared by substitution of WF with IBHP and IBLP at dose level of 5 kGy:

Data in Table (4) shows that, increasing of IBHP and IBLP substitution level increased the weight property, but no significant different between all samples treatment and control sample. This might be attributed to the higher fiber content for IBHP and IBLP which increased the weight. These results are in agreement with (Sankhon *et al.*, 2013; Khalifa *et*

*al.*, 2015). On the other hand, a significant increase in cake volume and Specific volume were noted with an increase in the IBHP and IBLP level. The control sample had the lowest value of weight, Volume and Specific volume compared to all samples. While the highest value of volume and specific volume were recorded in cake prepared from WF replacement with 1.5% IBHP and 1% IBLP, these values were (120cm<sup>3</sup> and 2.14cm<sup>3</sup>/g) and (126cm<sup>3</sup> and 2.13cm<sup>3</sup>/g) respectively. These results are in agreement with (Hafez, 2012; Al-Sayed and Ahmed, 2013; Sankhon *et al.*, 2013).

**Table (4) :** Weight, volume and specific volume of cake containing substituted flour with different levels of IBHP and IBLP at dose level of 5 kGy.

Substitution (%)		Weight (g)	Volume (cm <sup>3</sup> )	Specific volme(cm <sup>3</sup> /g)
Control		54 <sup>A</sup> ±1.61	98 <sup>E</sup> ±1.73	1.81 <sup>C</sup> ±0.023
IBHP	1.5%	56 <sup>A</sup> ±1.61	120 <sup>B</sup> ±1.89	2.14 <sup>A</sup> ±0.029
	3%	57.5 <sup>A</sup> ±1.21	114 <sup>D</sup> ±2.02	1.99 <sup>B</sup> ±0.005
	4.5%	56 <sup>A</sup> ±1.47	110 <sup>BC</sup> ±1.52	1.96 <sup>B</sup> ±0.041
IBLP	1%	59 <sup>A</sup> ±1.44	126 <sup>A</sup> ±1.44	2.13 <sup>A</sup> ±0.026
	2%	57.5 <sup>A</sup> ±1.21	116 <sup>BC</sup> ±1.15	2.02 <sup>B</sup> ±0.023
	3%	56.5 <sup>A</sup> ±1.84	113 <sup>CD</sup> ±1.60	2 <sup>B</sup> ±0.037

(Means ± SE).

A.B.C: Means with the same letter in the same column are not significantly different ( $p > 0.05$ ).

#### Hunter-lab color values of different cake treatments as affected by substitution of WF with IBHP and IBLP at dose level of 5 kGy:

All color data are expressed as Hunter L\*, a\* and b\* values corresponding to lightness, redness, and yellowness, respectively. The results of Hunter-lab color for cake produced by using 100% WF as a control sample and cake samples which substituted with 1.5, 3, 4.5% IBHP as well as 1, 2, 3% IBLP immediately after processing are presented in **Table (5)**.

From these data, it could be observed that, increasing of IBHP and IBLP substitution level decreased the Lightness(L\*), redness(a\*), yellowness (b\*), Chroma and total intensity values of the crust for all cake treatments compared to control sample. Also, these data showed that, increasing of IBHP and IBLP substitution level decreased the Lightness (L\*), redness (a\*) and total intensity values of the crumb. But, it was increased the yellowness (b\*) and Chroma values of the crumb for all cake treatments compared to control sample. These results are in agreement with (Sankhon *et al.*, 2013).

The crumb of the control cake was lighter and more yellow compared to the tested cakes. It was

well known that during cake baking, the crumb, does not reach temperatures above 100°C, so the Millard or caramelization reactions fail to take place. Therefore, the resulted of crumb color of tested cake was due to the color of the used substituted materials and their interactions (Gomez *et al.*, 2008).

In general, the changes in crust and crumb color of different cake treatments as affected by substitution of WF with IBHP and leaf powders might be attributed to the green color in the broccoli caused by the presence of chlorophyll pigment.

#### Total phenolic compounds and antioxidant activity of different WF cakes substituted with IBHP and IBLP at dose level of 5 kGy:

The total phenolic compounds content (TPC) and the DPPH radical scavenging activities of all formulated cakes were investigated; data is presented in **Table (6)**.

From these data it could be found that non-significant differences ( $p > 0.05$ ) were noticed in TPC content between all cake sample treatments and control sample. Excepting, the cake sample containing 2% IBLP where it had the highest TPC content being 1.66 (mg GAE g<sup>-1</sup>). Also, these results showed that, increasing of IBHP and IBLP substitution level increased the TPC content.

On the other hand a significant increase in the DPPH radical scavenging activities of all cake samples was noted with an increase in the IBHP and IBLP level. The highest DPPH radical scavenging activities were recorded in the cake sample containing 3% IBHP being 7.82%, followed by the cake sample containing 2% IBLP being 7.57%. While the control sample had the lowest TPC content and

DPPH radical scavenging activity being 1.19 (mg GAE g<sup>-1</sup>) and 2.95%, respectively.

In general, the results in Table (6) showed that, increasing of IBHP and IBLP substitution level increased the TPC content and the DPPH radical scavenging activities compared to control sample. This may be due to that increasing of phytochemicals as a result of increasing of IBHP and IBLP levels.

**Table (5) :** Hunter-lab color values of cake with different levels IBHP and IBLP powder at dose level of 5 kGy.

Substitution %	Crust					Crumb					
	L*	a*	b*	Chroma	Total intensity	L*	a*	b*	Chroma	Total intensity	
Control	48.21	17.46	30.39	35.05	59.6	74.82	8.30	28.63	29.81	80.54	
IBHP	1.5%	47.98	12.93	28.55	31.34	57.31	63.16	4.81	28.90	29.29	69.62
	3%	45.44	11.47	26.67	29.03	53.92	59.30	4.39	29.58	29.9	66.41
	4.5%	43.05	9.96	24.50	26.44	50.52	56.53	2.80	30.33	30.46	64.21
IBLP	1%	47.09	8.87	26.73	28.16	54.87	59.53	2.87	30.86	30.99	67.11
	2%	43.62	5.87	23.92	24.63	50.09	57.20	0.64	32.32	32.33	65.70
	3%	41.49	4.13	24.05	24.4	48.13	53.35	-2.16	32.29	32.21	62.32

(L\*): Lightness, (a\*): redness, (b\*): yellowness.

**Table (6) :** Total phenolic compounds and antioxidant activity of different WF cakes substituted with IBHP and IBLP at dose level of 5 kGy.

Substitution (%)	TPC (mg GAE g <sup>-1</sup> )	DPPH (%)
Control	1.19 <sup>B</sup> ±0.043	2.95% <sup>C</sup> ±0.153
IBHP	1.5%	1.27 <sup>B</sup> ±0.055
	3%	1.32 <sup>B</sup> ±0.046
	4.5%	1.22 <sup>B</sup> ±0.055
IBLP	1%	1.31 <sup>B</sup> ±0.057
	2%	1.66 <sup>A</sup> ±0.033
	3%	1.20 <sup>B</sup> ±0.066

(Means ± SE)

A.B.C: Means with the same letter in the same column are not significantly different ( $p > 0.05$ ).

The Antioxidant activity could enhance the bakery products shelf-life stability and retain the oil oxidation especially in cake products using the sources that may provide phytochemicals as natural components, like fruit, vegetable and their residues. These results are in accordance with those obtained by (Lu *et al.*, 2010; Ahmed, 2014; Badr, 2015; Khalifa *et al.*, 2015).

**Microbiological quality attributes of cake containing IBHP and IBLP at dose level of 5 kGy at difference levels during storage at room temperature for 18 day:**

It could be observed from the data in Table (7) that control sample had higher total bacterial and mold & yeasts counts as compared to other

cake samples which prepared with IBHP and IBLP at any time of storage at room temperature for 18 days. The total bacterial and mold & yeasts counts of cake samples fortified with IBHP and IBLP were decreased with increasing the percentage of replacement (1.5, 3 and 4.5%) for IBHP and (1, 2 and 3) for IBLP These results are in agreement with those obtained by (Ibrahim *et al.*, 2013) who found the microbial number in cake decreased as the percent of Clove essential oil. It is clear from the table that the total bacterial count and mold & yeasts were very low at zero time of storage (<100 cfu /g). Also, from the same table, it could be noticed that, total bacterial and mold & yeasts counts of all cake treatments were also affected by storage period.

**Table (7) :** Hunter-lab color values of cake with different levels IBHP and IBLP powder at dose level of 5 kGy.

Total bacterial counts (cfu/g)	Storage period (days)	Control	Treatments					
			IBHP			IBLP		
			1.5%	3%	4.5%	1%	2%	3%
0	8x10 <sup>1</sup>	6x10 <sup>1</sup>	5x10 <sup>1</sup>	5x10 <sup>1</sup>	7x10 <sup>1</sup>	8x10 <sup>1</sup>	6x10 <sup>1</sup>	
6	22x10 <sup>2</sup>	18x10 <sup>2</sup>	19x10 <sup>2</sup>	16x10 <sup>2</sup>	19x10 <sup>2</sup>	18x10 <sup>2</sup>	18x10 <sup>2</sup>	
12	63x10 <sup>2</sup>	54x10 <sup>2</sup>	49x10 <sup>2</sup>	48x10 <sup>2</sup>	52x10 <sup>2</sup>	44x10 <sup>2</sup>	41x10 <sup>2</sup>	
18	49x10 <sup>3</sup>	35x10 <sup>3</sup>	32x10 <sup>3</sup>	29x10 <sup>3</sup>	37x10 <sup>3</sup>	29x10 <sup>3</sup>	18x10 <sup>3</sup>	
Coliform bacterial counts ( cfu/g)	0	N.D	N.D	N.D	N.D	N.D	N.D	
	6	N.D	N.D	N.D	N.D	N.D	N.D	
	12	N.D	N.D	N.D	N.D	N.D	N.D	
	18	N.D	N.D	N.D	N.D	N.D	N.D	
Salmonella counts (cfu/g)	0	N.D	N.D	N.D	N.D	N.D	N.D	
	6	N.D	N.D	N.D	N.D	N.D	N.D	
	12	N.D	N.D	N.D	N.D	N.D	N.D	
	18	N.D	N.D	N.D	N.D	N.D	N.D	
Mold and Yeasts (cfu/g)	0	6x10 <sup>1</sup>	5x10 <sup>1</sup>	5x10 <sup>1</sup>	4x10 <sup>1</sup>	6x10 <sup>1</sup>	4x10 <sup>1</sup>	
	6	12x10 <sup>2</sup>	11x10 <sup>2</sup>	9x10 <sup>2</sup>	9x10 <sup>2</sup>	10x10 <sup>2</sup>	10x10 <sup>2</sup>	
	12	59x10 <sup>2</sup>	54x10 <sup>2</sup>	51x10 <sup>2</sup>	47x10 <sup>2</sup>	56x10 <sup>2</sup>	52x10 <sup>2</sup>	
	18	64x10 <sup>3</sup>	58x10 <sup>3</sup>	59x10 <sup>3</sup>	56x10 <sup>3</sup>	59x10 <sup>3</sup>	55x10 <sup>3</sup>	

N.D: not detected.

The total bacterial and mold & yeasts counts were increased in control sample and other treatments with increasing storage time up to 18 days of storage, but at different counts depending on the type of added plant portion and their percentages.

On the other hand, the increase in total bacterial counts after zero time until the end of storage period for control and all cake treatments may be due to increasing simple nitrogen compound (such as amino acid) and fatty acids produced by hydrolysis of protein and fat during storage consequently lead to suitable conditions for growth of microorganisms. While, the increase rates of total bacterial and mold & yeasts counts for the samples containing IBHP and IBLP were lower than that control of sample during storage at room temperature for 18 day. This might be attributed to the effect of the antimicrobial compounds in broccoli. This opinion is in agreement with (Abdalla *et al.*, 2007; Somaie *et al.*, 2013). On the other hand, Coliform group and Salmonella weren't detected in all cakes during the storage period. These results agree with those obtained by (Khalifa *et al.*, 2015). They recorded that coliform group wasn't detected in cake product and it also agree with those obtained by (Sahari and Asgari, 2013), who recorded the absence of *salmonella spp.* in Bakery Products.

#### **Sensory properties of cake prepared by substitution of WF with IBHP and IBLP at dose level of 5 kGy:**

The effect of partial replacement with different ratio of IBHP (1.5, 3 and 4.5%) and IBLP at levels (1, 2 and 3%) on the organoleptic quality characteristics of produced cake during storage at room temperature for 18 days is presented in **Table(8)**. From the sensory evaluation results, it could be seen that, there were non-significant differences in appearance, taste and overall acceptability between the control cake and cake prepared by adding 1.5% and 1% IBHP and IBLP, respectively, but significant differences in appearance could be observed between cake prepared

by adding (3, 4.5%) and (2, 3%) IBHP and IBLP, respectively compared to control cake sample. Also, from the same results, it could be observed that, there were no significant differences in crust color between control cake sample and cake prepared by adding 1.5% IBHP, but significant differences in appearance could be observed between other different cake samples (except cake prepared by adding 1% IBLP after 12 and 18 days) compared to control cake sample.

For crumb color, there were significant differences between control cake sample and all different cake samples, excepted cake prepared by adding 1.5% IBHP after 18 days.

Concerning the odor, it could be observed that, there were no significant difference between the control sample and cake prepared by all replacement levels.

From the same data in **Table (8)**, it could be noticed that the control cake sample recorded the highest scores in all organoleptic characteristics except odor, while cake prepared by adding 3% IBLP recorded the lowest scores in all organoleptic characteristics except odor, followed by cake prepared by adding 4.5% IBHP.

Change in color, odor and taste in cake may be due to aroma volatiles in raw materials used and also due to caramelization and millered reaction, as the protein contributed must have reached with the reduced sugar during the making process (Dhingra and Jood, 2004).

From these results, it could be observed that, there was a gradual decrease in all sensory characteristics for all different cake samples during storage periods.

The sensory characteristics liking results pointed out that a partial replacement of cake flour with less than or equal to (4.5 and 3%) IBHP and IBLP, respectively in cake is satisfactory. This opinion is in agreement with (Lu *et al.*, 2010).

**Table (8) : Sensory properties of cake different treatments as affected by IBHP and IBLP at dose level of 5 kGy during storage at room temperature for 18 day.**

Treatment	Control	IBHP			IBLP		
		1.5%	3%	4.5%	1%	2%	3%
<b>Storage (days)</b>	<b>Appearance</b>						
0	9.5 <sup>Aa</sup> ±0.16	9.2 <sup>Aa</sup> ±0.23	8.4 <sup>Abc</sup> ±0.19	7.8 <sup>Acd</sup> ±0.25	8.9 <sup>Aab</sup> ±0.20	7.9 <sup>Acd</sup> ±0.27	7.2 <sup>Ad</sup> ±0.28
6	8.9 <sup>ABa</sup> ±0.25	8.8 <sup>ABa</sup> ±0.33	7.9 <sup>Abc</sup> ±0.18	7.5 <sup>ABcd</sup> ±0.37	8.5 <sup>Aab</sup> ±0.27	7.5 <sup>ABcd</sup> ±0.30	6.8 <sup>Ad</sup> ±0.24
12	8.1 <sup>Ba</sup> ±0.25	7.9 <sup>Ba</sup> ±0.39	7.1 <sup>Bbc</sup> ±0.15	6.8 <sup>Bc</sup> ±0.17	7.7 <sup>Bab</sup> ±0.15	6.9 <sup>BCc</sup> ±0.28	5.9 <sup>Bd</sup> ±0.30
18	7.1 <sup>Ca</sup> ±0.37	6.8 <sup>Cab</sup> ±0.34	6.3 <sup>Cab</sup> ±0.20	5.9 <sup>Cbc</sup> ±0.23	6.5 <sup>Cab</sup> ±0.29	6.1 <sup>Cb</sup> ±0.28	5.2 <sup>Bc</sup> ±0.28
<b>Crust color</b>							
0	9.1 <sup>Aa</sup> ±0.21	8.4 <sup>Aab</sup> ±0.31	7.7 <sup>Abc</sup> ±0.26	7.1 <sup>Acd</sup> ±0.25	8.1 <sup>Ab</sup> ±0.28	7.6 <sup>Abc</sup> ±0.24	6.8 <sup>Ad</sup> ±0.23
6	8.6 <sup>ABa</sup> ±0.22	7.9 <sup>Aab</sup> ±0.34	7.3 <sup>ABbc</sup> ±0.22	6.5 <sup>ABcd</sup> ±0.26	7.7 <sup>ABb</sup> ±0.27	7.1 <sup>ABbc</sup> ±0.27	6.1 <sup>ABd</sup> ±0.24
12	8 <sup>Ba</sup> ±0.29	7.4 <sup>ABab</sup> ±0.38	6.8 <sup>BCbcd</sup> ±0.25	6.1 <sup>BCde</sup> ±0.22	7.1 <sup>Babc</sup> ±0.25	6.4 <sup>BCde</sup> ±0.32	5.7 <sup>BCe</sup> ±0.30
18	6.9 <sup>Ca</sup> ±0.27	6.5 <sup>Bab</sup> ±0.35	6.1 <sup>Cab</sup> ±0.19	5.6 <sup>Cbc</sup> ±0.21	6.1 <sup>Cab</sup> ±0.19	5.8 <sup>Cbc</sup> ±0.52	5 <sup>Cc</sup> ±0.27
<b>Crumb color</b>							
0	8.8 <sup>Aa</sup> ±0.22	7.9 <sup>Ab</sup> ±0.33	6.6 <sup>Acd</sup> ±0.17	6 <sup>Ad</sup> ±0.28	7.1 <sup>Ac</sup> ±0.31	6.2 <sup>Ad</sup> ±0.25	5.1 <sup>Ac</sup> ±0.22
6	8.4 <sup>ABa</sup> ±0.22	7.5 <sup>Ab</sup> ±0.41	6.2 <sup>Acd</sup> ±0.26	5.7 <sup>ABd</sup> ±0.23	6.6 <sup>ABC</sup> ±0.23	5.9 <sup>Acd</sup> ±0.24	4.8 <sup>ABe</sup> ±0.27
12	7.7 <sup>Ba</sup> ±0.24	6.9 <sup>ABb</sup> ±0.34	5.5 <sup>Bc</sup> ±0.16	5.1 <sup>BCc</sup> ±0.28	5.9 <sup>BCc</sup> ±0.22	5.1 <sup>Bc</sup> ±0.27	4.1 <sup>BCd</sup> ±0.25
18	6.8 <sup>Ca</sup> ±0.30	6.1 <sup>Ba</sup> ±0.39	5 <sup>Bb</sup> ±0.17	4.6 <sup>Cbc</sup> ±0.22	5.3 <sup>Cb</sup> ±0.23	4.5 <sup>Bbc</sup> ±0.22	3.8 <sup>Cc</sup> ±0.27
<b>Taste</b>							
0	8.4 <sup>Aa</sup> ±0.21	7.8 <sup>Aa</sup> ±0.34	6.9 <sup>Ab</sup> ±0.18	5.7 <sup>Ac</sup> ±0.28	7.9 <sup>Aa</sup> ±0.23	6.5 <sup>Ab</sup> ±0.26	5.5 <sup>Ac</sup> ±0.32
6	7.8 <sup>Aa</sup> ±0.25	7.2 <sup>ABa</sup> ±0.38	6.1 <sup>Bb</sup> ±0.20	5.2 <sup>ABbc</sup> ±0.32	7.4 <sup>ABa</sup> ±0.35	5.8 <sup>ABb</sup> ±0.29	4.6 <sup>Bc</sup> ±0.22
12	6.9 <sup>Ba</sup> ±0.28	6.4 <sup>BCa</sup> ±0.44	5.4 <sup>Cb</sup> ±0.20	4.5 <sup>BCcd</sup> ±0.20	6.7 <sup>Ba</sup> ±0.22	5.1 <sup>BCbc</sup> ±0.28	3.8 <sup>BCd</sup> ±0.29
18	5.5 <sup>Ca</sup> ±0.28	5.3 <sup>Cab</sup> ±0.34	4.5 <sup>Dc</sup> ±0.18	3.7 <sup>Ccd</sup> ±0.27	5.8 <sup>Ca</sup> ±0.25	4.3 <sup>Cc</sup> ±0.29	3.1 <sup>Cd</sup> ±0.27
<b>Odor</b>							
0	8.3 <sup>Aa</sup> ±0.31	8 <sup>Aa</sup> ±0.36	7.8 <sup>Aa</sup> ±0.22	7.5 <sup>Aa</sup> ±0.24	8.2 <sup>Aa</sup> ±0.25	8.1 <sup>Aa</sup> ±0.22	7.9 <sup>Aa</sup> ±0.33
6	7.8 <sup>ABa</sup> ±0.25	7.7 <sup>ABa</sup> ±0.23	7.6 <sup>ABa</sup> ±0.19	7.2 <sup>Aa</sup> ±0.27	7.8 <sup>ABa</sup> ±0.29	7.6 <sup>ABa</sup> ±0.22	7.5 <sup>Aa</sup> ±0.31
12	6.7 <sup>BCa</sup> ±0.37	7 <sup>BCa</sup> ±0.12	7.1 <sup>Ba</sup> ±0.22	6.8 <sup>ABa</sup> ±0.22	7.3 <sup>BCa</sup> ±0.28	7.2 <sup>ABa</sup> ±0.23	7.2 <sup>ABa</sup> ±0.28
18	6.1 <sup>Ca</sup> ±0.33	6.5 <sup>Ca</sup> ±0.16	6.4 <sup>Ca</sup> ±0.19	6.4 <sup>Ba</sup> ±0.17	6.8 <sup>Ca</sup> ±0.22	6.6 <sup>Ba</sup> ±0.57	6.5 <sup>Ba</sup> ±0.24
<b>Overall acceptability</b>							
0	8.9 <sup>Aa</sup> ±0.18	8.5 <sup>Aab</sup> ±0.22	7.8 <sup>Abc</sup> ±0.24	6.5 <sup>Ad</sup> ±0.30	8.2 <sup>Aab</sup> ±0.31	7.3 <sup>Ac</sup> ±0.24	5.9 <sup>Ad</sup> ±0.27
6	8.3 <sup>ABa</sup> ±0.29	8 <sup>ABa</sup> ±0.22	7 <sup>Bb</sup> ±0.22	6.1 <sup>ABcd</sup> ±0.31	7.8 <sup>Aa</sup> ±0.27	6.8 <sup>ABbc</sup> ±0.29	5.5 <sup>ABd</sup> ±0.29
12	7.9 <sup>Ba</sup> ±0.28	7.7 <sup>Ba</sup> ±0.22	6.4 <sup>Bb</sup> ±0.15	5.4 <sup>BCc</sup> ±0.25	7.4 <sup>Aa</sup> ±0.19	6.1 <sup>BCb</sup> ±0.25	4.8 <sup>BCc</sup> ±0.25
18	6.9 <sup>Ca</sup> ±0.38	6.7 <sup>Ca</sup> ±0.22	5.5 <sup>Cb</sup> ±0.16	4.9 <sup>Cbc</sup> ±0.34	6.5 <sup>Ba</sup> ±0.27	5.3 <sup>Cbc</sup> ±0.31	4.4 <sup>Cc</sup> ±0.35

(Means ± SE)

A.B.C: Means with the same letter in the same column are not significantly different ( $p > 0.05$ ).

a.b.c: Means with the same letter in the same row are not significantly different ( $p > 0.05$ ).

## CONCLUSIONS

The present study indicated the possibility of formulating cake using different levels of IBHP and IBLP at dose level of 5 KGy as partial replacement of WF (72%) to produce a low caloric cake with improvement the nutritional value, bioactive components, antioxidant and antimicrobial benefits to cakes during room temperature storage. In addition to, the properties of IBHP and IBLP were changed the sensory cakes characteristics, as the odor became more specific, the sensation for sweetness was weaker, the color of the crust and the crumb was green-brown. The shape and the crumb tenderness were discernible, but close to those of the control cake. Also the cakes containing IBHP and IBLP showed satisfactory physical properties.

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## الصفات الطبيعية والكيميائية والحسية للكيك المدعم بمسحوق البروكلي المشع

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تهدف هذه الدراسة إلى إنتاج كيك مرتفع القيمة الغذائية ومرتفع المحتوى من المركبات المضادة للأكسدة والمضادة للميكروبات ومنخفض السعرات الحرارية، ففى هذه الدراسة تم تشييع مسحوق كل من رؤوس وأوراق البروكلي بجرعات صفر، ٣، ٥، ٧ كيلو جراى من أشعة جاما. وقد أظهرت النتائج أن المستخلص الإيثانولى بتركيز ٧٠٪ لمسحوق الرؤوس والأوراق المعامل بجرعة إشعاعية ٥ كيلوجراى كان يحتوى على أعلى نسبة من المركبات الفينولية وأكثر فاعلية كمضاد للأكسدة مقارنة بمستخلصات الرؤوس والأوراق المعاملة بجرعات صفر، ٣، ٧ كيلو جراى، وبناء على ذلك فقد تم اختيار مسحوق الرؤوس والأوراق المعاملة بجرعة ٥ كيلو جراى كأفضل معاملة للحصول على مركبات ذات نشاط مضادة للأكسدة يمكن تطبيقها فى تصنيع الكيك، حيث تم عمل استبدال جزئي لدقيق القمح (٧٢٪) باستخدام مستويات استبدال مختلفة لكل من مسحوق رؤوس وأوراق البروكلي المشعة (١،٥، ٣، ٤،٥، ٦،٢، ٣٪) بالنسبة للرؤوس، (١، ٢، ٣٪) بالنسبة للأوراق وذلك كنسبة مئوية من كمية الدقيق المستخدمة فى تركيبة الكيك. وأظهرت النتائج أن إضافة كلا من مسحوق رؤوس وأوراق البروكلي المشعة الى الكيك كبديل جزئي للدقيق أدى إلى تحسين التركيب الكيماوي للكيك الناتج مقارنة بعينات الكنترول حيث زادت نسبة كلا من البروتين، الدهون، الألياف والرماد وانخفضت نسبة كلا من الكربوهيدرات وقيم الطاقة (السعرات الحرارية)؛ كما أدت هذه الإضافة أيضا إلى زيادة محتوى الكيك الناتج من المركبات الفينولية وزيادة النشاط المضاد للأكسدة وكذلك زيادة الحجم والنوعى مقارنة بعينات الكنترول. وبالنسبة للخصائص الميكروبيولوجية فقد أظهرت النتائج أن الاستبدال نتج عنه انخفاض تعداد الميكروبات فى المنتج وخاصة مع زيادة نسبة الاستبدال. ومن ناحية أخرى تأثرت بعض الصفات الفيزيائية والحسية للكيك، حيث انخفضت كل قيم اللون بالنسبة للطبقة الخارجية، بينما بالنسبة للطبقة الداخلية فقد انخفضت بعض قيم اللون وازدادت بعضها، وذلك تناسبيا مع زيادة نسبة الاستبدال. وبالنسبة للصفات الحسية فقد تأثرت بعض صفات الكيك وخاصة مع زيادة نسب الاستبدال، ولكن على الرغم من ذلك كانت جيدة أو مقبولة. وعموما كانت نتائج الاستبدال بنسب ٣، ٢ من الدقيق برؤوس البروكلي وأوراقه على التوالي مرضية. ولذا ينصح بالاستفادة من البروكلي لإرتفاع محتواه من المركبات الفينولية فى تصنيع كيك عالى القيمة الغذائية ومنخفض السعرات الحرارية ومقبول لدى المستهلك.

1. قسم الصناعات الغذائية- كلية الزراعة- جامعة بنها- مصر.

2. قسم البحوث النباتية- مركز البحوث النووية- هيئة الطاقة الذرية- انشاص- مصر.

