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Use of yellow pigment extracted from turmeric (*Curcuma longa*) rhizomes powder as natural food preservative and colorant

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ABSTRACT

This investigation was carried out to extract yellow pigment from powder of turmeric (*Curcuma longa*) rhizomes by using acetone and hexane solvents (2:3 v/v). Then, concentrated the oleoresin-containing solvent (yellow pigment extract) for development of both liquid to obtain water-soluble and oil-soluble yellow pigment color. Moreover, evaluate the preservative/antioxidant activity of oil-soluble yellow pigment at concentrations 0.5, 0.1 and 0.2% (w/w) in soybean oil after accelerated oxidation at 65°C for 7 days compared with soy bean oil free from antioxidant (control), with 0.02% butylated hydroxytoluene (BHT) (synthetic antioxidant). In addition, use of sensory evaluation to select the best ratio of water-soluble yellow pigment at ratios 0, 1, 3 and 5% (w/w) to blend with chicken breast fillet samples for improving the color, flavor and appearance. Then, the results of sensory evaluation showed that the ratio of 3% (w/w) of water-soluble yellow pigment was the best ratio to blend with chicken breast fillet samples. Thus, based on the results of sensory evaluation the effects of combined treatment of water-soluble yellow pigment at ratio 3% (w/w) as natural colorant, antimicrobial and antioxidant and gamma irradiation at dose levels of 1, 3 and 5 kGy on the microbiological, chemical and sensory characteristics of chicken breast fillet samples during cold storage (4±1°C) to extend the shelf-life of chicken breast fillets were investigated. The results revealed that the addition of 0.2% oil-soluble yellow pigment caused detectable increments in the oxidative stability of soy bean oil compared with control and other treatments under investigation. On the other hand, the sensory evaluation of chicken breast fillets samples blended with different ratios from water-soluble yellow pigment (0, 1, 3 and 5% w/w) extracted from turmeric powder as natural food colorant was carried out firstly to select the best ratio improved the color, flavor and appearance. The results presented that ratio of 3% water-soluble yellow pigment were selected for improving color, flavor and appearance compared with the other ratios (1 and 5%). The results showed that the ratio of 3% of water-soluble yellow pigment reduced the total bacterial count, Psychrophilic bacteria, lactic acid bacteria, enterobacteriaceae, total molds and yeasts, *Staphylococcus aureus*, *Bacillus cereus*, *Enterococccus faecalis* and *Salmonella* spp, was not detected in all treated samples. Also, shelf-life periods were increased 39 days for chicken breast fillet samples treated by 3% water-soluble yellow pigment and gamma radiation at dose level of 5 kGy. Thus, these results illustrate that yellow pigment extracted from turmeric rhizomes exhibit strong antioxidant and antimicrobial activities. Therefore the use of these yellow pigment extracts in food is recommended to suppress lipid oxidation and may be useful as natural food colorant and preservative and an alternative to synthetic dyes that are harmful to health effects.

Key words: Yellow pigment/ Turmeric/ Colorant/ Food/ Preservative.

INTRODUCTION

Color is one of the most important sensory qualities as it helps us to accept or reject particular food items. Color is important in consumer perception of food and it is often associated with a specific flavour and intensity of flavor. Color is used to add or restore color of a food in order to enhance its visual appeal and to match consumer expectations (Saltmarsh, 2000). Presently, there is an increased global trend towards usage of natural colours in food, pharmaceutical and personal care industries. Much awareness is created amongst consumers regarding natural products and adopting a more natural way of life. Currently, people prefer natural food, herbal medicines, natural curing practices and even organic farming i.e. without using chemical fertilizers and pesticides. This is mostly due to the rampant use of synthetic chemicals, colors, and derived products that has lead to various human health hazards. Due to the adverse effect of synthetic dyes, all countries have made strict regulations about the permitted colors to be used as food additives (Kappor, 2006).

Consumers are avoiding foods containing synthetic colourants, which lead food industries to replace them by natural pigments. Food colorants may be classified into synthetic, nature-identical, inorganic and natural colorants. Natural colorants for food are made from renewable sources. Most often, the colorants are extracted from plant material, but other sources such as insects, algae and fungi are used as well (Aberoumand, 2011). The advantages of using natural colorants are many as they are eco-friendly, safe for body contact, unsophisticated and harmonized with nature, obtained from renewable sources and also their preparation involves a minimum

possibility of chemical reactions. Generally natural dyes do not cause health hazards; on the contrary, they sometimes act as a health cures like turmeric and annatto etc. Furthermore, the use of natural dyes offers no disposal problems (Kumar and Sinha, 2004).

Turmeric (*Curcuma longa*) rhizome, an important tropical spice, which is a member of the ginger family Zingiberaceae (Aggarwal et al., 2005). The rhizomes of turmeric provide a yellow, flavorful powder when dried and ground and have long been used in Chinese medicines (Joshi et al. 2009). Turmeric has also attracted considerable attention over the years due to its use in the food industry as a coloring agent (Aggarwal et al. 2003). Unlike synthetic dyes such as tartrazine and carmoisine that may impair liver function and cause oxidative stress, many natural pigments are used not only as food coloring, but also as a substance that promotes health and well being by preventing or even healing diseases (Amin et al. 2010).

Turmeric (*Curcuma longa*) is a spice commonly used to impart yellow color at household level, mostly for spicy preparation, however its direct use for sweet products is mostly limited due to its typical flavor and taste. Turmeric and its extract have various beneficial effects on human health (Nishiyama et al. 2005). Curcumin, the major coloring principal present in turmeric, can be extracted and used as a natural food color. These pigments can be used as food coloring and flavoring agents in the food industry as substitutes for synthetic dyes like tartrazin (Govindarajan, 1980). Turmeric owes its characteristic yellow color to three major pigments; curcumin (50-60%), demethoxy curcumin (20-30%) and bis demethoxy curcumin (7-20%) (Khurana and Ho, 1988). All these curcuminoids are known to have antioxidant activities (Toda et al. 1985). Some pigments can act as both a colorant and a preservative for food. Amongst these, curcumin is an important natural colorant used in food, which has a wide range of pharmacological activities (Sampathu et al. 2000). It has anti-microbial effects against many microorganisms, especially against *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus* (Egan et al., 2004). Moreover, it can inhibit the growth of *Bacillus typhi*, and *Bacillus dysenteriae*. Free curcumin has a good preservation effect on cooked mutton, bread and bean curd (Liang et al. 2007).

Thus, The objective of this study was carried out to extract of yellow pigment from turmeric rhizomes (powder form) by using acetone and hexane solvents (2:3 v/v). Then, concentrated the oleoresin-containing solvent (yellow pigment extract) for development of both liquid to obtain water-soluble and oil-soluble yellow pigment color. In addition to evaluate the preservative/antioxidant activity of oil-soluble yellow pigment in soybean oil after accelerated oxidation at 65°C. Moreover, the results of sensory evaluation showed that the ratio of 3% (w/w) of water-soluble yellow pigment was the best ratio to blend with chicken breast fillet samples. So, based on the results of sensory evaluation the effects of combined treatment of water-soluble yellow pigment at ratio 3% (w/w) as natural colorant, antimicrobial and antioxidant and gamma irradiation at dose levels of 1, 3 and 5 kGy on the microbiological, chemical and sensory characteristics of chicken breast fillet samples during cold storage (4±1°C) to extend the shelf-life of chicken breast fillets were investigated.

MATERIALS & METHODS

Turmeric rhizome samples

The dried rhizome of turmeric procured from local market were cleaned were cleaned and ground to fine powder.

Chicken breast fillets

Deboned chicken breast fillets of freshly slaughtered carcasses were purchased from EL-Sharkia Poultry Company at Bilbies City, Sharkia Governorate, Egypt.

Preparation of yellow pigment (water-soluble and oil-soluble yellow pigment) extract from turmeric powder samples.

The samples of dry turmeric were extracted using acetone and hexane (2:3 v/v) (AOAC, 2000). The oleoresin-containing solvent (yellow pigment extract) were concentrated by rotary evaporate under vacuum at 40°C and placed in a glass bottle and stored at 4°C until used. Then, the water-soluble turmeric yellow pigment or the liquid color was developed from oleoresin (50 mL concentrate) by adding 10 mL of polysorbate (Tween 80) followed by mixing in mixer for 2 min. The oil-soluble turmeric yellow pigment in petroleum ether and hence used for crystallisation. To 50 mL of concentrated oleoresin in alcohol 100 mL of petroleum ether was slowly added and vertexed manually for 10 min and let it stand for 30 min. The top layer was decanted, concentrated under vacuum at 40°C and placed in a glass bottle and stored at 4°C until used (Joshi et al. 2009).

Soy bean oil (Refined and free from artificial antioxidants) was purchased from Arma for food industry Co., 10th of Ramadan and butylated hydroxytoluene (BHT) as a synthetic antioxidant, was purchased from Naarden International Company.

Oven test

The oven test method suggested by Cocks and Rede (1966).

Peroxide value

Peroxide value was determined according to the method described in the A.O.C.S. (1993).

Thiobarbaturic acid value (TBA)

Thiobarbaturic acid values were carried out according to the described by Ottolenghi (1959).

Preparation of chicken breast fillets blended with water-soluble turmeric yellow pigment

Samples of chicken breast fillets blended with the best ratio of water-soluble yellow pigment (3%)**.** The samples were packaged in tightly sealed polyethylene pouches (100±2g) and divided into four groups, the first used was control, second was treated samples at ratio of 3% water- soluble yellow pigment, third irradiated samples at dose levels of 0, 1, 3 and 5 kGy, fourth treated samples with 3% of water-slouble yellow pigment and irradiated at dose levels of 1, 3 and 5 kGy. Then, all samples were stored at cold storage (4±1°C) for sensory evaluation.

Irradiation Treatments:

For irradiation treatments, all chicken breast fillets groups were exposed to gamma irradiation at doses of 1, 3 and 5 kGy using an experimental ^{60}Co Russian gamma chamber, in Cyclotron Project, Nuclear Research Center, Atomic Energy Authority, Abou Zaabal, Egypt. After irradiation, all samples were subjected to analysis.

Sensory Evaluation

Irradiated and non-irradiated prepared chicken breast fillets samples were periodically examined (every 3 days) for their appearance, texture and odor post treatments and during cold storage at 4±1ºC to determine the shelf-life of the samples. The panel consisted of ten members from our laboratory and scores were obtained as described by Wierbicki (1985) by rating the above quality characteristics using the following rating scale: 9= Excellent, 8= Very good, 7= Good, 6= Below Good-above fair, 5= Fair, 4= Below fair-above poor, 3= Poor, 2= Very poor and 1= Extremely poor.

Microbiological Analysis:

Colony forming units for total bacterial count were counted by plating on plate count agar medium and incubation at 30^{o}C for 3-5 days(APHA, 1992). Lactic acid bacteria were counted by the pour plate over layer method on MRS medium Oxoid manual (1982). Enterobacteriaceae were counted on violet red bile glucose agar medium after incubation for 20–24 h at 37^{o}C Roberts et al., (1995).Total molds and yeasts were counted on oxytetracycline glucose yeast extract agar medium according to Oxoid manual (1998),then the plates were incubated at 25^{o}C for 3-5 days. *Staphylococcus aureus* was counted using Baird–Parker medium after incubated at 35^{o}C for 24–48 h Oxoid manual (1998). *Enterococcus faecalis* was counted on kanamycin aesculine azide agar medium using surface plating technique and incubation at 35ºC for 16 - 24 h according to the Oxoid manual (1998). Colonies were considered as *Enterococcus faecalis* if they were porcelain white and surrounded by a black zone. *Bacillus cereus* was counted using Mannitol-egg Yolk-Polymyxin (MYP) agar and incubated at 37ºC for 16-24 hours as described by Roberts et al., (1995). The detection of *Salmonella* was carried out using the most probable number technique. After enrichment at 37^{o}C for 24 h in selenite broth, the cultures were streaked on Brilliant green agar and incubated at 37^{o}C for 24 h, then colonies were biochemically examined in triple sugar iron agar (IOS, 1978).

Chemical Analysis

Total volatile basic nitrogen (TVBN) was determined as described by Mwansyemela, (1992).

Measurement of lipid peroxidation:

Thiobarbaturic acid value (TBARS)

2-thiobarbituric acidreacting substances (TBARS) values of the raw ground and cooked meat. The values were expressed as mg malonaldehyde/kg of sample. The methods described by Koniecko (1979)

Statistical Analysis

The obtained data were exposed to analysis of variance. Duncan's multiple range test at 5% level was used to compare between means. The analysis was carried out using the PROC ANOVA procedure of Statistical Analysis System (SAS, 1996).

RESULTS & DISCUSSIONS

Stability of sunflower oil as affected by addition of oil-soluble yellow pigment extracted from turmeric rhizomes powder

The oxidative stabilities of soy bean oil free from antioxidant (control), with 0.02% (200 ppm) BHT (synthetic antioxidant), 0.05%, 0.1% and 0.2% of oil-soluble yellow pigment extracted from turmeric rhizomes powder. Oven test was used as a rapid method to detect oxidative rancidity from the reaction with atmospheric oxygen, in which one day storage at 65^{o}C equal to 7 days to accelerate oxidation. Thiobarbeturic acid (TBA) and Peroxide values (PV) were used to determine the oxidative stability.

Peroxide values

The results in Table (1) showed that the effect of synthetic antioxidant and different concentrations of oil-soluble yellow pigment extracted from turmeric rhizomes powder on peroxide value (meq/kg) of soy bean oil stored at 65^{o}C for 7 days. The increases of peroxide values are the best predictors of fat deterioration, which

could be used to monitor the extent of oil spoilage. The oxidation rate of soy bean oil was reduced by adding of oil-soluble yellow pigment extracted from turmeric rhizomes powder. Inhibition oxidation of oil-soluble yellow pigment extract increased with increasing its concentration in treated soybean oil. Development of rancidity in soy bean oil was affected by temperature and storage time. A gradual increase in peroxide value of treated soy bean oil was observed during storage for 7 day at 65°C. The peroxide value of control sample increased from 1.24 to 22.86 after 4 days of storage at 65°C. The peroxide values of oil-soluble yellow pigment extract (0.1 and 0.2%) had significantly (higher inhibition of soy bean peroxidation than that of synthetic antioxidants. These concentrations extended the induction period to reach a peroxide value of 20 meq/kg in soybean oil under tested conditions (65°C) over 7 days and BHT 5 days. However, there was no distinct difference between synthetic antioxidants (BHT) and oil-soluble yellow pigment extracts 0.05 and 0.1% in inhibition of soy bean oil peroxidation. Maillard et al. (1996) mentioned that phenolic compounds are known to act as antioxidants not only due to their ability to donate hydrogen or electron but also attributed to their stable radical intermediates, which prevent the oxidation of various food ingredients particularly fatty acids and oil. The antioxidant mechanism of curcumin is attributed to its unique conjugated structure, which shows typical radical-trapping ability as a chain-breaking antioxidant (Chattopadhyay et al., 2004). Moreover, Khanna (1999) recorded that the antioxidant property of turmeric was effective in preventing peroxide developments in foods. Also Lean and Mohamed (1999) too reported strong antioxidant activity by turmeric in butter cakes.

Thiobarbituric acid (TBA) values

The effect of synthetic antioxidant and different concentrations of oil-soluble yellow pigment extracted from turmeric rhizomes powder on peroxide value (meq/kg) of soy bean oil stored at 65^{o}C for 7 days are tabulated in Table (2). TBA values gradually increased with an increase in storage period for all soy bean oil samples. Soy bean oils treated with antioxidants had lower TBA values than control. However, the addition of oil-soluble yellow pigment extract (0.2%) lowered the final TBA value after 7 days. TBA measure the formation of secondary oxidation products, which may contribute to the off-flavor of oxidized oil. Duh et al. (1997) reported that lower TBARS (Thiobarbituric acid-reactive substances) during accelerated oxidation of soy bean oil at 60C in the presence of mung bean hulls extract (100 ppm) than with the same concentration of BHA after 10 days of storage. Jitendra et al. foun that the peroxide value , TBA and free fatty acid values were lowest in turmeric 5000 ppm and highest in nitrite 200 ppm in samples of raw minced chicken stored at 4 ± 1°C.

Sensory evaluation of chicken breast fillets samples blended with different ratios of water-soluble yellow pigment extracted from turmeric powder as natural food colorant

The results in Table (3) obvious the sensory evaluation of chicken breast fillets samples blended with different ratios from water-soluble yellow pigment (0, 1, 3 and 5% w/w) extracted from turmeric powder as natural food colorant. The data revealed that no diffeenrt significantly in flavor samples of chicken breast fillets blended with different ratios from water-soluble yellow pigment (1, 3 and 5% w/w) compared with control samples. Moreover, the results showed that no different significantly in color and appearance of control and chicken breast fillets samples blended with ratio of 3% water-soluble yellow pigment. Also, the data illustrated that different significantly in color and appearance samples of chicken breast fillets blended with ratios of 1 and 5 % water-soluble yellow pigment in comparison with samples of control and chicken breast fillets blended with ratio of 3% water-soluble yellow. On based these results of sensory evaluation, the samples of chicken breast fillets blended with ratio of 3% water-soluble yellow pigment had high scores and improved the color, flavor and appearance compared with treated samples with ratios of 1 and 5% water-soluble yellow pigment. Jitendra et al. (2012) found that turmeric is a food color; rather it is a functional food additive. This functional aspect of turmeric use in meat foods merits further research.

Thus, the ratio of 3% water-soluble yellow pigment were selected to study the combined effect of gamma irradiation at dose levels of 1, 3 and 5 kGy and ratio of 3% water-soluble yellow pigment as natural food colorant, antimicrobial antioxidant on the chemical, microbiological and sensory qualities of chicken breast fillets samples during cold storage at 4±1^{o}C.

Microbial load

The common causes for spoilage of refrigerated processed meat foods are microbiological deterioration and lipid oxidation; whereas the major limiting factor for frozen products is lipid oxidation, which may affect acceptability of food because of rancidity, and it may decrease the nutritional value by forming potential toxic products during cooking and processing (Maillard et al., 1996). The data in Table (4) exhibit that the effects of combination treatments between gamma irradiation and the ratio of 3% water-soluble yellow pigment extracted from turmeric powder on the microbial load in chicken breast fillets samples during cold storage at 4±1^{o}C. The samples of chicken breast fillets had initial counts of $7.1x10^{5}$, $3.5x10^{4}$ and $2.3x10^{3}$ cfu/g for total bacterial counts, psychrophilic bacteria and lactic acid bacteria, respectively. The high level for initial bacterial counts

may be due the possible contamination during handling procedures, dividing and packing of chicken breast fillets samples. Tawfik et al. (2007) reported that control (non irradiated) ready-to-eat cooked beef burger steaks had initial counts of 8.7 $x10^4$ and 4.2 $x10^5$ cfu/g for total bacterial and psychrophilic bacteria, respectively. Mattar and Abdeldaiem (2008) found that chicken burger had initial counts of 2.6 $x10^6$ and 4.1 $x10^5$ cfu/g for total bacterial and lactic acid bacteria, respectively. In addition, Table (4) shows that treatment of chicken breast fillets with 3% water-soluble yellow pigment extracted from turmeric rhizomes powder reduced slightly the total bacterial, psychrophilic bacteria and lactic acid bacteria, whereas irradiation exposure of chicken breast fillets to dose levels of 1, 3 and 5 kGy markedly decreased the total bacterial, psychrophilic bacteria and lactic acid bacteria. Moulds and yeast are widely distributed in the environment and participate as the normal food flora. The initial count of total moulds and yeast and enterobacteriaceae were 6.5 $x10^4$ and 8.5 $x10^2$ cfu/g, respectively, in control samples of chicken breast fillets. Irradiation of these samples at dose levels of 3 and 5 kGy caused decrease in the initial counts of the total mould and yeast reached 1.1 $x10^4$ and 4.8 $x10^2$ cfu/g, respectively, and there was no colony growth of enterobacteriaceae neither post-irradiation nor during cold storage till 42 day (end of the experiment time). In control samples when total count was exceed than maximum acceptable level of 1 $x10^7$ cfu/g (Anomymous, 1991), this leads to the rejection of the stored control samples. In the present study, the control samples were rejected at more than 6 days of storage and accept samples treated with 3% water-soluble yellow pigment extracted from turmeric rhizomes powder till 9 days of storage and 3 and 5 kGy irradiated samples till 30 and 39 days of storage, respectively. Wang et al. (2009) found that curcumin had antifungal activity and spoilage microbes such asst *Aspergillus niger*, *Penicillium notatum and Saccharomyces cerevisiae*.

The treatment of foods with ionizing radiation in the form of gamma rays can produce beneficial effects such as inhibiting the growth of fungi pasteurizing fresh meat, poultry and seafood and sterilizing spices and food additives (Cleland et al. 2004). The use of multiple antimicrobial treatments for decontamination meat might provide a greater barrier to microbial survival and proliferation of beef by taking advantage of different weakness of differing microbial strains (Pohlman et al. 2002).

Food borne pathogens

Presentation of outbreak of food borne disease that are caused by pathogenic microorganisms and prevention of microbial spoilage of meat that leads to loss in the human health and economic society are very important (Motamedee et al. 2003).

Table (5) illustrates the effects of combination treatments between gamma irradiation and the ratio of 3% water-soluble yellow pigment extracted from turmeric powder on the on food borne pathogens in chicken breast fillets during cold storage at 4±1^{o}C. It is clear that the 3% water-soluble yellow pigment extract inhibited the growth of *Salmonella* and active against *S. aureus*, *Bacillus cereus* and *Enterococccus faecalis*. Egan et al. (2004) reported that curcumin is an important natural colorant used in food, and it has anti-microbial effects against many microorganisms, especially against *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus*. Furthermore, Liang et al. (2007) found that the curcumin can be inhibited the growth of *Bacillus typhi*, and *Bacillus dysenteriae* and curcumin has a good preservation effect on cooked mutton, bread and bean curd. In the present study the growth of *Salmonella*, *S. aureus*, *Bacillus cereus* and *Enterococccus faecalis* was completely inhibited at irradiation dose levels of 3 and 5 kGy, respectively. From these results it is clear that the combined effect of treatment of chicken breast fillets with 3% water-soluble yellow pigment extracted from turmeric powder and gamma irradiation at dose levels of 3 and 5 kGy accepted till 30 and 39 days of storage, respectively. Food spoilage is caused by the action of microorganisms among other factors. The food can be preserved when the basic causes of its spoilage is controlled. The sensitivity of pathogenic microorganisms against gamma irradiation has been extensively studied (Hammad et al. 2000; Tawfik et al. 2007). Wang et al. (2009) reported that curcumin microcapsules had a broad-spectrum inhibitory effect against foodborne pathogens and spoilage microbes such as *E. coli*, *Yersinia enterocolitica*, *S. aureus*, *B. subtilis* and *Bacillus cereus*.

Chemical evaluation

Total volatile basic nitrogen (TVBN) is considered stability test and index to microbial decomposition of muscle protein of meat products (Hammad et al. 2000). Table (6) shows that the TVBN in control samples (12.90 mg N/100g) was increased markedly to 28.64 mg N/100g after 6 days. Also, TVBN in chicken breast fillets treated with 3% water-soluble yellow pigment extracted from turmeric powder was increased to 27.53 mg N/100g after 9 days of storage. From this table, it is clear that TVBN in irradiated chicken breast fillets at dose levels of 1, 3 and 5 kGy was increased significantly by increasing the storage period. The combined treatment of chicken breast fillets with 3% water-soluble yellow pigment extracted from turmeric powder and gamma irradiation at dose level of 5 kGy increased the TVBN to 33.42 mg N/100g after 39 days of storage. From table (6) thiobarbituric acid-reactive substances (TBARS) (mg malonaldehyde/kg) of control, treated with 3% water-soluble yellow pigment extract and gamma irradiated chicken breast fillets were increased by increasing the storage period. Motterlini et al. (2000) reported that it has the ability to inhibit lipid peroxidation and scavenge

the superoxide anion and hydroxyl radicals. In addition to its inherent ability to attenuate the reactivity of oxygen free radical species, curcumin has shown to enhance the detoxifying enzyme activities such as glutathione- S-transferase in vivo. Also, Chattopadhyay et al. (2004) found that In vitro, curcumin significantly inhibited the generation of reactive oxygen species (ROS) like superoxide anions, H_2O_2 and nitrite radical generation by activated macrophages. It also has decreased lipid peroxidation in rat liver microsomes, erythrocyte membranes and brain homogenates.Tawfik et al. (2007) mentioned that at the end of storage period, TBARS and –SH values of beef burger steaks were further increased. The slight increase in values of TBARs in treated with 3% water-soluble yellow pigment extracted from turmeric powder and irradiated samples compared with control samples. The slight increases in the TBARS may be mainly attributed to the strong antioxidant effect of water-soluble yellow pigment extract which acts as a radical scavenger. Meanwhile, the results illustrated that the rate increases in values of TBARS were lower in treated with 3% WWT samples and samples of irradiated treated with 3% WWT at dose levels of 1, 3 and 5 kGy than irradiated samples at dose levels of 1, 3 and 5 kGy. This may be due to effect of add of water-soluble yellow pigment to samples under investigation before its irradiated probably may be delayed the lipid oxidation in these samples. Cousins et al. (2007) curcuminoids, such as curcumin, demethoxycurcumin and bisdemethoxycurcumin, are yellowish turmeric pigments, and have antioxidative, anticarcinogenic, anti-inflammatory, antihepatotoxic and hypocholesterolemic activities. These curcuminoids are major antioxidative compounds of turmeric. Jitendra et al. foun that the peroxide value , TBA and free fatty acid values were lowest in turmeric 5000 ppm and highest in nitrite 200 ppm in samples of raw minced chicken stored at 4 ± 1°C. The acceptability limit of TBARS value in this study was 1.0. Earlier workers reported that meat sample containing TBARS value less than 1 possesses no off odor (Tarladgis et al. 1960). Meanwhile, Jayasingh et al. (2002) reported that for secondary oxidation products, such as, TBA, no legal threshold exists, but a limit of 1 mg malonaldehyde/kg meat has been suggested for sensory perceived rancidity.

Sensory evaluation

Sensory attributes for appearance, odor and texture of chicken breast fillets as affected by combined treatments between water-soluble yellow pigment extracted from turmeric powder (3% WWT) and gamma irradiation during cold storage (4±1ºC) are shown in Table (7). Sensory evaluation showed that gamma irradiation and treatment with 3% WWT was better in appearance, odor and texture than control samples. The results indicated that the samples radiated at dose level of 5 kGy and treated with 3% WWT were effective to ensure safety of chicken breast fillets samples end of 39 days of storage at 4±1°C. Upon cold storage, samples of control and treated with 3% water-soluble yellow pigment extracted from turmeric powder similar scores till the detection off odor and their total bacterial count more than $1x10^7$ cfu/g and their rejection on day 6 and 12 of storage, respectively. While, samples of combined treatments treated with 3% WWT and gamma irradiation at doses of 0, 1, 3 and 5 kGy were scored as good samples their rejection due to increasing their total bacterial count to more than $1x10^7$ cfu/g on day 24, 33 and 42 of storage, respectively. Hammad et al. (2003) and Tawfik et al. (2007) reported that the panelists could be not differentiate between irradiated minced meat at low dose of radiation (3 kGy) and the quality was accepted during period storage of 30 days. Maurya et al. (2010) observed that turmeric showed a significant effect in controlling oxidative rancidity of fat of carabeef pastirma.

CONCLUSION

Generally, it can be concluded that the yellow pigment extracted from turmeric powder can be used as good natural preservative (antioxidant and antimicrobial) and source to develop yellow color with desirable properties for samples under investigation as soy bean oil and chicken breast fillets stored under refrigeration (4 ± 1°C). Thus, this study recommended that yellow pigment extracted from turmeric powder useful as natural food colorant and preservative in many products and an alternative to synthetic dyes that are harmful to health effects.

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Table (1): Effect of synthetic antioxidant and different concentrations of oil-soluble yellow pigment extracted from turmeric rhizomes powder on peroxide value (meq/kg) of soy bean oil stored at 65°C for 7 days.

Storage period (days)	Control	BHT (0.02%)	Concentrations of oil-soluble yellow pigment extracted from turmeric powder		
			0.05%	0.1%	0.2%
0	1.24^{Aa}	1.24^{Aa}	1.24^{Aa}	1.24^{Aa}	1.24^{Aa}
1	7.32^{Ab}	2.45^{Bb}	1.75^{Ca}	1.67^{Ca}	1.43^{Ca}
2	11.41^{Ac}	2.71^{Bb}	1.83^{Ca}	1.95^{Ca}	1.65^{Ca}
3	17.53^{Ad}	5.03^{Bc}	2.44^{Cb}	2.09^{Cb}	1.82^{Da}
4	22.86^{Ae}	11.52^{Bd}	2.87^{Cb}	2.34^{Cb}	1.95^{Da}
5	31.67^{Af}	18.96^{Be}	9.39^{Cc}	2.88^{Db}	2.71^{Eb}
6	40.08^{Ag}	27.33^{Bf}	20.18^{Cd}	7.05^{Dc}	3.56^{Ec}
7	49.35^{Ah}	39.12^{Bg}	37.54^{Ce}	18.76^{Dd}	11.48^{Ed}

Capital and small letters were used for comparison between means in the rows and columns.
Means with the same letters are not significantly different (p>0.05).

Table (2): Changes occurred in thiobarbituric acid (TBA) value of stored soy bean oil as affected by addition of BHT and different concentrations of oil-soluble yellow pigment extracted from turmeric rhizomes powder at 65°C for 7 days .

Storage period (days)	Control	BHT (0.02%)	Oil-soluble yellow pigment extracted from turmeric powder		
			0.05%	0.1%	0.2%
0	0.048^{Aa}	0.048^{Aa}	0.048^{Aa}	0.048^{Aa}	0.048^{Aa}
1	0.066^{Ab}	0.052^{Bb}	0.051^{Bb}	0.050^{Bb}	0.049^{Ba}
2	0.083^{Ac}	0.059^{Bb}	0.057^{Bb}	0.052^{Bb}	0.051^{Bb}
3	0.097^{Ad}	0.065^{Bc}	0.063^{Bc}	0.055^{Cb}	0.053^{Cb}
4	0.13^{Ae}	0.068^{Bc}	0.065^{Bc}	0.059^{Cb}	0.055^{Cb}
5	0.21^{Af}	0.071^{Bd}	0.069^{Cc}	0.064^{Dc}	0.059^{Eb}
6	0.32^{Ag}	0.075^{Bd}	0.082^{Cd}	0.069^{Dc}	0.062^{De}
7	0.44^{Ah}	0.079^{Bd}	0.085^{Cd}	0.073^{Bd}	0.065^{De}

Capital and small letters were used for comparison between means in the rows and columns.
Means with the same letters are not significantly different (p>0.05).

Table (3): Sensory evaluation of chicken breast fillets samples blended with different ratios of water-soluble yellow pigment extracted from turmeric powder as natural food colorant.

Blending ratios (w/w)	Color	Flavor	Appearance
Control	$9.8^{A}\pm0.27$	$9.8^{A}\pm0.35$	$9.7^{A}\pm0.15$
1%	$8.4^{B}\pm0.35$	$9.7^{A}\pm0.41$	$8.6^{B}\pm0.36$
3%	$9.7^{A}\pm0.19$	$9.7^{A}\pm0.25$	$9.4^{A}\pm0.49$
5%	$7.8^{C}\pm0.48$	$9.6^{A}\pm0.16$	$8.6^{C}\pm0.25$

Capital letters were used for comparison between means in the columns.
Means with the same letters are not significantly different (p>0.05).

Table (4): Effects of combination treatments between gamma irradiation and the ratio of 3% water-soluble yellow pigment extracted from turmeric rhizomes powder on the microbial load in chicken breast fillets samples during cold storage at 4±1°C.

Microbial determinations (cfu/g)	Storage period (days)	Control	WWT (3%)	Irradiated chicken breast fillets (kGy)			Combined treatment		
				1	3	5	A	B	C
Total bacterial count	0	$7.1x10^5$	$5.2x10^5$	$4.7x10^5$	$1.7x10^4$	$3.9x10^3$	$7.2x10^4$	$7.7x10^3$	$6.1x10^2$
	3	$4.5x10^6$	$8.4x10^5$	$9.4x10^5$	$8.5x10^4$	$6.4x10^3$	$9.8x10^4$	$9.5x10^3$	$8.8x10^2$
	6	$9.7x10^6$	$2.6x10^6$	$7.1x10^6$	4.3x105	$8.3x10^3$	$3.4x10^5$	$3.6x10^4$	$2.4x10^3$
	9	$6.5x10^7$R	$7.3x10^6$	$8.5x10^6$	$9.1x10^5$	$4.7x10^4$	$5.9x10^5$	$6.8x10^4$	$5.9x10^3$
	12		$5.8x10^7$R	$2.6x10^7$R	$4.2x10^6$	$9.6x10^5$	$8.6x10^5$	$8.9x10^4$	$7.6x10^3$
	15				$1.5x10^7$R	$5.5x10^6$	$1.4x10^6$	$4.1x10^5$	$2.7x10^4$
	18					$8.8x10^6$	$4.9x10^6$	$6.3x10^5$	$6.4x10^4$
	21					$4.9x10^7$R	$7.3x10^6$	$9.9x10^5$	$1.6x10^5$
	24						$3.7x10^7$R	$3.1x10^6$	$3.8x10^5$
	27							$5.5x10^6$	$6.3x10^5$
	30							$9.1x10^6$	$9.1x10^5$
	33							$4.2x10^7$R	$2.6x10^6$
	36								$4.8x10^6$
	39								$7.3x10^6$
	42								$2.6x10^7$R
Psychrophilic bacteria	0	$3.5x10^4$	$3.7x10^4$	$6.4x10^3$	$8.7x10^2$	$4.8x10^1$	$6.5x10^3$	$8.8x10^2$	$4.6x10^1$
	3	$6.1x10^4$	$6.5x10^4$	$8.7x10^3$	$1.9x10^3$	$6.9x10^1$	$8.1x10^3$	$9.6x10^2$	$6.9x10^1$
	6	$8.4x10^4$	$8.2x10^4$	$9.9x10^3$	$4.4x10^3$	$8.8x10^1$	$9.3x10^3$	$3.4x10^3$	$8.5x10^1$
	9	$9.2x10^5$R	$3.9x10^5$	$2.7x10^4$	$8.2x10^3$	$3.5x10^2$	$2.3x10^4$	$5.2x10^3$	$1.9x10^2$
	12		$8.9x10^5$R	$5.5x10^4$R	$3.7x10^4$	$6.8x10^2$	$4.5x10^4$	$7.7x10^3$	$4.8x10^2$
	15					$9.1x10^2$	$7.2x10^4$	$8.9x10^3$	$6.6x10^2$
	18					$5.9x10^3$	$8.9x10^4$	$2.5x10^4$	$7.8x10^2$
	21					$2.8x10^4$R	$2.7x10^5$	$4.7x10^4$	$9.3x10^2$
	24						$6.8x10^5$R	$7.5x10^4$	$2.8x10^3$
	27							$9.7x10^4$	$5.6x10^3$
	30							$4.8x10^5$	$8.4x10^3$
	33							$8.5x10^5$R	$4.3x10^4$
	36								$7.7x10^4$
	39								$1.5x10^5$
	42								$4.6x10^5$R
Lactic acid bacteria	0	$2.3x10^3$	$1.7x10^3$	$9.4x10^4$	$1.9x10^4$	$4.4x10^3$	$4.6x10^2$	$2.2x10^1$	$6.9x10^1$
	3	$4.5x10^3$	$3.7x10^3$	$3.2x10^5$	5.2x104	$8.6x10^3$	<10	<10	<10
	6	$8.1x10^3$	$5.2x10^3$	$6.9x10^5$	$7.9x10^4$	$3.7x10^4$	<10	<10	<10
	9	$5.4x10^4$R	$7.6x10^3$	$9.7x10^5$	$4.3x10^5$	$7.2x10^4$	<10	<10	<10
	12		$2.4x10^4$R	$3.8x10^6$R	$8.7x10^5$	$9.9x10^4$	<10	<10	<10
	15				$2.4x10^6$R	$3.2x10^5$	<10	<10	<10
	18					$6.6x10^5$	$2.6x10^2$	<10	<10
	21					$9.6x10^5$R	$4.2x10^2$	<10	<10
	24						$9.4x10^3$R	$1.6x10^2$	<10
	27							$5.5x10^2$	<10
	30							$8.6x10^2$	$8.0x10^1$
	33							$6.3x10^3$R	$2.5x10^2$
	36								$5.7x10^2$
	39								$9.8x10^2$
	42								$4.5x10^3$R
Enterobacteriaceae	0	$8.5x10^2$	$6.2x10^2$	$6x10^1$	Nil	Nil	Nil	Nil	Nil
	3	$3.5x10^3$	$8.5x10^2$	$1.4x10^1$	Nil	Nil	Nil	Nil	Nil
	6	$7.7x10^3$	$3.1x10^3$	$2.5x10^2$	Nil	Nil	Nil	Nil	Nil
	9	$2.6x10^4$R	$6.9x10^3$	$4.6x10^2$	Nil	Nil	Nil	Nil	Nil
	12		$8.7x10^3$R	$6.7x10^2$R	Nil	Nil	Nil	Nil	Nil
	15				Nil R	Nil	Nil	Nil	Nil
	18					Nil	Nil	Nil	Nil
	21					Nil R	Nil	Nil	Nil
	24						Nil R	Nil	Nil
	27							Nil	Nil
	30							Nil	Nil
	33							Nil R	Nil
	36								Nil
	39								Nil
	42								Nil R
Total molds and yeasts	0	$6.5X10^4$	$2.1x10^4$	$9.1x10^3$	$1.1x10^3$	$4.8x10^2$	$4.4x10^3$	$5.7x10^2$	$1.1x10^2$
	3	$8.9x10^4$	$4.9x10^4$	$2.3x10^4$	3.6x103	$8.5x10^2$	$5.3x10^3$	$6.2x10^2$	$2.9x10^2$
	6	$1.7x10^5$	$7.8x10^4$	$5.9x10^4$	$6.6x10^3$	$2.7x10^3$	$6.9x10^3$	$7.8x10^2$	$5.2x10^2$
	9	$4.1x10^5$R	$8.9x10^4$	$9.7x10^4$	$9.1x10^3$	$6.6x10^3$	$7.5x10^3$	$8.9x10^3$	$7.8x10^2$
	12		$5.3x10^5$R	$3.4x10^5$R	$4.1x10^4$	$8.6x10^3$	$8.7x10^3$	$9.6x10^3$	$2.1x10^3$
	15				$6.8x10^4$R	$1.6x10^4$	$9.9x10^3$	$1.7x10^4$	$4.7x10^3$
	18					$4.9x10^4$	$2.8x10^4$	$3.1x10^4$	$8.2x10^3$
	21					$7.3x10^4$R	$4.5 x10^4$	$5.2x10^4$	$1.9x10^4$
	24						$6.9x10^4$R	$6.5x10^4$	$3.9x10^4$
	27							$8.4 x10^4$	$6.3x10^4$
	30							$9.8 x10^4$	$7.9 x10^4$
	33							$3.6x10^5$R	$9.1 x10^4$
	36								$1.8 x10^5$
	39								$3.4 x10^5$
	42								$7.5x10^5$R

WWT= Water-soluble yellow pigment extracted from turmeric powder

A= Irradiated chicken breast fillets with 3% WWT at dose level of 1 kGy
B= Irradiated chicken breast fillets with 3% WWT at dose level of 3 kGy
C= Irradiated chicken breast fillets with 3% WWT at dose level of 5 kGy
R= Rejected

Table (5): Effects of combination treatments between gamma irradiation and the ratio of 3% water-soluble yellow pigment extracted from turmeric powder on the on food borne pathogens in chicken breast fillets during cold storage at 4±1°C.

Microbial determinations (cfu/g)	Storage period (days)	Control	WWT (3%)	Irradiated chicken breast fillets (kGy)			Combined treatment		
				1	3	5	A	B	C
Staphylococcus aureus	0	$8.8x10^2$	$4.3x10^2$	$1.7x10^1$	Nil	Nil	$1.3x10^1$	Nil	Nil
	3	$2.5x10^3$	$6.9x10^2$	$3.3x10^1$	Nil	Nil	$3.3x10^1$	Nil	Nil
	6	$5.2x10^3$	$9.1x10^2$	$5.6x10^1$	Nil	Nil	$5.1x10^1$	Nil	Nil
	9	$7.3x10^3$R	$2.7x10^3$	$7.1x10^1$	Nil	Nil	$6.9x10^1$	Nil	Nil
	12		$4.4x10^3$R	$9.3x10^1$R	Nil	Nil	$8.6x10^1$	Nil	Nil
	15				Nil R	Nil	$2.4x10^2$	Nil	Nil
	18					Nil	$3.8x10^2$	Nil	Nil
	21					Nil R	$5.3x10^2$	Nil	Nil
	24						$8.6x10^2$R	Nil	Nil
	27							Nil	Nil
	30							Nil	Nil
	33							Nil R	Nil
	36								Nil
	39								Nil
	42								Nil R
Bacillus cereus	0	$7.3x10^2$	$5.1x10^2$				$7.9x10^1$	N.D	N.D
	3	$9.6x10^2$	$7.5x10^2$				$819x10^1$	N.D	N.D
	6	$2.9x10^3$	$8.4x10^2$				$2.7x10^2$	N.D	N.D
	9	$6.5x10^3$R	$2.8x10^3$				$4.9x10^2$	N.D	N.D
	12		$4.9x10^3$R				$5.5x10^2$	N.D	N.D
	15						$6.8x10^2$	N.D	N.D
	18						$7.9x10^2$	N.D	N.D
	21						$9.3x10^2$	N.D	N.D
	24						$2.7x10^3$R	N.D	N.D
	27							N.D	N.D
	30							N.D	N.D
	33							N.D R	N.D
	36								N.D
	39								N.D
	42								N.D R
Enterococccus faecalis	0	$3.9 x10^3$	$1.5 x10^3$	$7.9x10^1$	N.D	N.D	$4.5 x10^2$	N.D	N.D
	3	$5.2 x10^3$	$3.2 x10^3$	$9.3x10^1$	N.D	N.D	$5.6 x10^2$	N.D	N.D
	6	$7.8 x10^3$	$5.4 x10^3$	$2.1x10^2$	N.D	N.D	$6.9 x10^2$	N.D	N.D
	9	$1.8x10^4$R	$7.3 x10^3$	$3.9x10^2$	N.D	N.D	$8.1 x10^2$	N.D	N.D
	12		$2.6x10^4$R	$5.7x10^2$R	N.D	N.D	$9.7 x10^2$	N.D	N.D
	15				N.D R	N.D	$2.1 x10^3$	N.D	N.D
	18					N.D	$3.5 x10^3$	N.D	N.D
	21					N.D R	$4.9 x10^3$	N.D	N.D
	24						$7.3x10^3$R	N.D	N.D
	27							N.D	N.D
	30							N.D	N.D
	33							N.D R	N.D
	36								N.D
	39								N.D
	42								N.D R
Salmonella	0	+ve	-ve	-ve	N.D	N.D	N.D	N.D	N.D
	3	+ve	-ve	-ve	N.D	N.D	N.D	N.D	N.D
	6	+ve	-ve	-ve	N.D	N.D	N.D	N.D	N.D
	9	+ve R	-ve	-ve	N.D	N.D	N.D	N.D	N.D
	12		-ve R	-ve R	N.D	N.D	N.D	N.D	N.D
	15				N.D R	N.D	N.D	N.D	N.D
	18					N.D	N.D	N.D	N.D
	21					N.D R	N.D	N.D	N.D
	24						N.D R	N.D	N.D
	27							N.D	N.D
	30							N.D	N.D
	33							N.D R	N.D
	36								N.D
	39								N.D
	42								N.D R

WWT= Water-soluble yellow pigment extracted from turmeric powder
A= Irradiated chicken breast fillets with 3% WWT at dose level of 1 kGy
B= Irradiated chicken breast fillets with 3% WWT at dose level of 3 kGy

C= Irradiated chicken breast fillets with 3% WWT at dose level of 5 kGy
R= Rejected +ve = Positive -ve = Negative N.D= Not detected

Table(6): Effects of combination treatments between gamma irradiation and the ratio of 3% water-soluble yellow pigment extracted from turmeric powder on the on some chemical characteristics of chicken breast fillets during cold storage at 4±1°C.

Chemical quality index	Storage period (days)	Control	Chicken breast fillets blending with WWT (3%)	Irradiated chicken breast fillets (kGy)			Combined treatment		
				1	3	5	A	B	C
The total volatile basic nitrogen (TVBN mg N/100g wet matter)	0	12.90	12.97	13.64	14.07	14.98	13.82	14.31	14.75
	3	21.91	16.60	20.47	19.55	17.14	16.43	16.27	14.99
	6	28.64	20.54	27.88	23.41	19.62	21.34	18.71	15.88
	9	35.52 R	27.53	32.56	28.74	24.08	24.17	20.05	17.62
	12		34.38R	35.75R	30.62	27.13	26.48	22.92	19.03
	15				34.96R	29.26	28.93	23.38	20.42
	18					32.41	30.60	25.16	21.35
	21					35.18R	32.83	27.12	23.94
	24						36.07R	29.84	25.62
	27							30.99	26.77
	30							33.56	27.8
	33							35.16R	28.63
	36								30.87
	39								33.42
	42								35.9R
Thiobarbituric acid-reactive substances (mg malonaldehyde/kg)	0	0.21	0.21	0. 33	0.49	0.65	0. 23	0.25	0.28
	3	0.34	0.24	0. 47	0.68	0.69	0.24	0.34	0.33
	6	0. 59R	0.29	0.63	0.75	0.74	0.28	0.41	0.39
	9		0.41	0.73	0.81	0.78	0.35	0.48	0.42
	12		0. 67R	0.92R	0.89	0.81	0.52	0.63	0.49
	15				0.95R	0.84	0.71	0.69	0.56
	18					0.92	0.89	0.72	0.59
	21					1.22R	0.99	0.76	0.64
	24						1.53R	0.82	0.68
	27							0.85	0.73
	30							0.96	0.77
	33							1.17R	0.84
	36								0.89
	39								0.95
	42								1.64R

WWT= Water-soluble yellow pigment extracted from turmeric powder
A= Irradiated chicken breast fillets with 3% WWT at dose of 1 kGy
B= Irradiated chicken breast fillets with 3% WWT at dose of 3 kGy
C= Irradiated chicken breast fillets with 3% WWT at dose of 5 kGy
R= Rejected

Table(7):Sensory attributes of chicken breast fillets as affected by combined treatments between water-soluble yellow pigment extracted from turmeric powder (3% WWT) and gamma irradiation during cold storage (4±1°C).

Sensory attributes	Storage period (days)	Control	Chicken breast fillets blending with WWT (3%)	Irradiated chicken breast fillets			Combined treatment		
				1 kGy	3 kGy	5 kGy	A	B	C
Appearance	0	9.7^{Aa}±0.11	9.6^{Aa}±0.32	9.6^{Aa}±0.09	9.6^{Aa}±0.24	9.5^{Aa}±0.21	9.5^{Aa}±0.38	9.5^{Aa}±0.43	9.5^{Aa}±0.09
	3	9.6^{Aa}±0.41	9.5^{Aa}±0.44	9.5^{Aa}±0.21	9.5^{Aa}±0.39	9.5^{Aa}±0.25	9.5^{Aa}±0.47	9.5^{Aa}±0.39	9.5^{Aa}±0.7
	6	4.4^{Bb}±0.22R	9.5^{Aa}±0.51	9.4^{Aa}±0.17	9.5^{Aa}±0.28	9.5^{Aa}±0.24	9.5^{Aa}±0.43	9.5^{Aa}±0.27	9.5^{Aa}±0.06
	9		9.4^{Aa}±0.12	9.4^{Aa}±0.08	9.4^{Aa}±0.24	9.5^{Aa}±0.26	9.4^{Aa}±0.39	9.5^{Aa}±0.38	9.5^{Aa}±0.17
	12		3.8^{Bb}±0.16R	4.2^{Bc}±0.35R	8.6^{Bd}±0.27	9.5^{Aa}±0.31	9.4^{Aa}±0.28	9.5^{Aa}±0.37	9.5^{Aa}±0.18
	15				4.6^{Cc}±0.51R	8.7^{Ad}±0.38	9.4^{Aa}±0.38	9.5^{Aa}±0.29	9.5^{Aa}±0.12
	18					8.5^{Bd}±0.29	9.3^{Aa}±0.35	9.5^{Aa}±0.21	9.5^{Aa}±0.19
	21					4.3^{Cc}±0.06R	8.7^{Bd}±0.29	9.4^{Aa}±0.24	9.4^{Aa}±0.28
	24						5.3^{Ce}±0.28R	9.4^{Aa}±0.36	9.4^{Aa}±0.22
	27							8.7^{Bd}±0.41	9.4^{Aa}±0.26
	30							8.5^{Bd}±0.44	9.4^{A}±0.31
	33							5.2^{Ce}±0.22R	8.8^{Bd}±0.42
	36								8.4^{Bd}±0.14
	39								7.6^{Cf}±0.19
	42								4.9^{Dc}±0.35R
Odor	0	9.8^{Aa}±0.25	9.7^{Aa}±0.19	9.7^{Aa}±0.08	9.7^{Aa}±0.36	9.6^{Aa}±0.26	9.6^{Aa}±0.09	9.6^{Aa}±0.16	9.6^{Aa}±0.29
	3	9.7^{Aa}±0.28	9.7^{Aa}±0.12	9.7^{Aa}±0.09	9.7^{Aa}±0.38	9.6^{Aa}±0.22	9.6^{Aa}±0.09	9.6^{Aa}±0.15	9.6^{Aa}±0.34
	6	3.2^{Bb}±0.31R	9.7^{Aa}±0.11	9.7^{Aa}±0.07	9.7^{Aa}±0.29	9.6^{Aa}±0.25	9.6^{Aa}±0.07	9.6^{Aa}±0.12	9.6^{Aa}±0.37
	9		9.3^{Aa}±0.13	9.4^{Aa}±0.06	9.6^{Aa}±0.28	9.6^{Aa}±0.23	9.5^{Aa}±0.07	9.6^{Aa}±0.12	9.6^{A}±0.36
	12		3.3^{Bb}±0.42R	3.1^{Bb}±0.25R	9.5^{Aa}±0.21	9.3^{Aa}±0.29	9.5^{Aa}±0.06	9.5^{Aa}±0.17	9.6^{Aa}±0.27
	15				3.3^{Bb}±0.08R	9.2^{Aa}±0.29	9.5^{Aa}±0.05	9.4^{Aa}±0.24	9.5^{Aa}±0.19
	18					9.2^{Aa}±0.31	9.3^{Aa}±0.12	9.4^{Aa}±0.27	9.5^{Aa}±0.16
	21					3.4^{Bb}±0.37R	9.2^{Aa}±0.15	9.4^{Aa}±0.25	9.4^{Aa}±0.11
	24						3.5^{Bb}±0.46R	9.3^{Aa}±0.23	9.4^{Aa}±0.11
	27							9.2^{Aa}±0.32	9.4^{Aa}±0.14
	30							9.2^{Aa}±0.41	9.4^{Aa}±0.18
	33							3.2^{Bb}±0.44R	9.3^{Aa}±0.25
	36								9.3^{Aa}±0.24
	39								9.3^{Aa}±0.28
	42								3.3^{Bb}±0.39R
Texture	0	9.7^{Aa}±0.09	9.8^{Aa}±0.21	9.7^{Aa}±0.13	9.5^{Aa}±0.31	9.4^{Aa}±0.06	9.6^{Aa}±0.24	9.6^{Aa}±0.42	9.6^{Aa}±0.07
	3	9.7^{Aa}±0.07	9.8^{Aa}±0.22	9.7^{Aa}±0.15	9.5^{Aa}±0.31	9.4^{Aa}±0.06	9.6^{Aa}±0.28	9.6^{Aa}±0.39	9.6^{Aa}±0.13
	6	3.7^{Bb}±0.24R	9.7^{Aa}±0.21	9.7^{Aa}±0.13	9.5^{Aa}±0.38	9.4^{Aa}±0.0.12	9.5^{Aa}±0.24	9.6^{Aa}±0.39	9.6^{Aa}±0.13
	9		9.7^{A}a±0.28	9.7^{Aa}±0.19	9.4^{Aa}±0.29	9.4^{Aa}±0.18	9.5^{Aa}±0.23	9.5^{Aa}±0.42	9.6^{Aa}±0.14
	12		4.6^{Cb}±0.37R	3.4^{Bb}±0.27R	9.4^{Aa}±0.34	9.2^{Aa}±0.05	9.4^{Aa}±0.23	9.5^{Aa}±0.42	9.6^{Aa}±0.15
	15				4.2^{Cb}±0.28R	9.2^{Aa}±0.07	9.4^{Aa}±0.29	9.4^{Aa}±0.44	9.5^{Aa}±0.14
	18					9.1^{Aa}±0.13	9.1^{Aa}±0.34	9.4^{Aa}±0.45	9.5^{Aa}±0.16
	21					3.5^{Bb}±0.41R	8.6^{Eb}±0.33	9.4^{Aa}±0.37	9.5^{Aa}±0.19
	24						7.1^{Dc}±0.26R	9.3^{Aa}±0.33	9.4^{Aa}±0.08
	27							8.9^{Eb}±0.28	9.4^{Aa}±0.08
	30							8.8^{Eb}±0.26	9.1^{Aa}±0.31
	33							7.3^{Dc}±0.35R	9.1^{Aa}±0.37
	36								8.7^{Eb}±0.42
	39								8.5^{Eb}±0.45
	42								6.2^{Fc}±0.53R

Capital and small letters were used for comparing between means in the columns and rows, respectively.
Means with the same letters are not significantly different (p>0.05).
WWT= Water-soluble yellow pigment extracted from turmeric powder
A= Irradiated chicken breast fillets with 3% WWT at dose of 1 kGy
B= Irradiated chicken breast fillets with 3% WWT at dose of 3 kGy
C= Irradiated chicken breast fillets with 3% WWT at dose of 5 kGy
R= Rejected