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STORAGE STABILITY OF CHICKEN PATTIES AFTER TREATMENT WITH POMEGRANATE, POTATO AND APPLE PEEL EXTRACTS

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ABSTRACT. The goal of this study was to evaluate the comparative effect of alcoholic extracts of pomegranate peel powder (POMPEP), potato peel powder (POTPEP) and apple peel powder (APPPEP) on oxidative and microbial stability of chicken meat patties during frozen storage at −18 °C for 60 days. The formulations of meat products were treated with different freeze-dried alcoholic peel extracts (T1 – control; T2 – 1% POMPEP; T3 – 1% POTPEP and T4 – 1% APPPEP). Peroxide value (PV), thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), pH, total aerobic bacteria (TAB), and psychrophilic bacteria (PSB) counts were determined after 0, 15, 30, 45 and 60 days of storage. The addition of extracts led to a significant decrease in PV (13.62–26.82%), compared with control. Regarding the secondary oxidation products, the TBARS values of different patties decreased in the order of POMPEP > APPPEP > POTPEP > Control. FFA values of the POTPEP treated patties were significantly higher than in other extracts, whereas there were no significant differences in the pH values among studied extracts. TAB and PSB values of the treated patties were less than the maximum allowed value.

Introduction

Chicken meat and its products such as chicken patties occupied an important place in daily human food and have been increasing worldwide because of its excellent nutritional and quality properties, as they have low-fat contents and high polyunsaturated fatty acids (Darwish *et al.*, 2012; Cagdas, Kumcuoglu, 2015, Santos *et al.*, 2019; Chinprahast *et al.*, 2020). Chicken meat patties are susceptible to oxidative changes and microbial growth during frozen storage, and fat autoxidation induced by an aerobic conditions while microbial growth can cause by many factors such as increased level of moisture, protein, polyunsaturated fatty acids, simple nutrients (such as non-protein-nitrogen compounds) and pH (Santana Neto *et al.*, 2021). Both of the deterioration indicators above are the major reasons for reduced shelf life and quality value in chicken meat patties during storage (Jiang, Xiong, 2016; Turgut *et al.*, 2017). Due to using of synthetic antioxidant agents has been found to exhibit toxicological effects, plant-origin phenolics are natural sources of antioxidants and are considered by consumers as better and safer than synthetic agents (Naveena *et al.*, 2008; Devatkal *et al.* 2011). Therefore, peels of fruit are produced as waste during fruit processing industry and contain phenolic compounds with antioxidant and antimicrobial activities can be used to minimize changes in quality attributes of the chicken patties during processing and storage and also, they have acceptance by consumers (Vaithiyanathan *et al.*, 2011; Bazargani-Gilani *et al.*, 2015).

Nowadays, the application of natural-origin antioxidants and antimicrobial extracts in the chicken meat industry is largely increased (Sharma, Yadav, 2020). One of the excellent sources of bioactive compounds is food technology by-products such as pomegranate, apple and potato peels. Furthermore, the peels contain valuable compounds compared with other different parts (Rahnemoon *et al.*, 2021). Tannins, anthocyanins and flavonoids, ellagitannins, proanthocyanidin, gallic acid, punicalagin, ellagic acid, quercetin, p-coumaric acid, caffeic acid, vanillic acid and other phenolic compounds are present in pomegranate, apple, and potato, especially in the peel and are

represent bioactive phenolic compounds (Kanatt *et al.*, 2005; Qu *et al.*, 2012; Sabally *et al.*, 2016; Colle *et al.*, 2019; Barkhordari, Bazargani-Gilani 2021; Das *et al.*, 2021).

Recently, antioxidant and antibacterial effects of many plant peel extracts in different chicken meat products had been documented (Kanatt *et al.*, 2010; Mantihal *et al.*, 2021). However, there is little published study available on the incorporation of ethanolic extract of pomegranate, apple, and potato peels in chicken patties during frozen storage, therefore, the present research was undertaken to find out the influence of those extracts as a natural antioxidant and antibacterial on some quality characteristics of chicken patties samples stored in LDPE (low density polyethylene) bags under freezing at −18 °C for 60 days.

Materials and Methods

Sample preparation

Iraqi whole chicken meat (freshly slaughtered and deboned) was purchased from the local chicken market; pomegranate (*Punica granatum L.*), green apple (*Pyrus malus L.*) and potato (*Solanum tuberosum*) were procured from a local market in Mosul city, Ninevah governorate, Republic of Iraq. All chemical materials used in the experiments research were of analytical grade.

Alcoholic extract powder preparation

The preparation of alcoholic extract powder for the peels of pomegranate, apple and potato was carried out according to the procedure described by Wafa *et al.* (2017). The fruits used in this research were washed under running water, cut manually by using a knife and peeled off. The obtained peels were further cut by a sharp knife into small pieces and air-dried at 60 °C till constant weight. Dried pieces were powdered using an electric grinder to a fine powder. The peels were lastly packed in polyethene bags and stored at freezing temperature before extraction. For extraction, each peel extract powder was soaked with 70% ethanol for 48 h in a water bath with shaking. The ratio of mixing was 1:20 w/v. After cooling and filtering the extracts, the supernatant of each alcoholic peel extract was concentrated in a vacuum rotary evaporator (IKA, Germany). The concentrate was freeze drying to obtain alcohol soluble powder which was stored in brown bottles until further use.

Preparation of chicken meat patties

Table 1 shows the different ingredients used in the chicken patties formulation, and they were prepared using chicken thigh and skin. Meat samples were ground twice at 12- and 5-mm plates respectively, by using a pilot mincer, ten kilograms of chicken meat were prepared to make chicken patties. Chicken meat formulation samples were treated as follows (Table 1): T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP). Thoroughly mixing was done between extracts and other components of each formulation of chicken meat patties. The moulding of meat patties (100 g) was made in a patty former. Packaging of each sample of chicken meat patties was conducted in LDPE bags and stored at freezing for 60 days at −18 °C. Each patty was withdrawn at 0, 15, 30, 45 and 60 days and tested for peroxide values (PV), thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), pH, total aerobic bacteria counts (TAB) and psychrophilic bacteria counts (PSB), with three replicates.

Table 1. Chicken meat patties formulations were used in this research

Ingredient type, %	Treatments			
	T1	T2	T3	T4
Minced chicken thigh	80	80	80	80
Minced chicken skin	10	10	10	10
Water	8.9	7.9	7.9	7.9
Dry mixture of spice	0.1	0.1	0.1	0.1
Salt	1	1	1	1
POMPEP		1		
POTPEP			1	
APLPEP				1

T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP).

Determinations

Peroxide value

The peroxide number of chicken patties samples was performed using the titration method described by AOAC (2010), with some modification and expressed in milliequivalents per kilogram (meq O_2 kg^{-1}) of the sample. A chicken patties 5 g sample was weighed and mixed with 30 ml glacial acetic acid-chloroform solution as a mixture ratio of 2:3 in a 250 ml glass-stoppered flask. The mixture was thoroughly agitated for 3 min. Next, 0.5 ml of saturated potassium iodide (KI) solution was put into the flask. The mixture was left in the dark for 10 minutes, followed by the addition of 30 ml of distilled water and starch solution indicator with a concentration of 1%. The titration of the flask contents with 0.01 N sodium thiosulphate standard solution was conducted till the endpoint was reached (disappearance of colour). The peroxide results were expressed as milliequivalents (meq O_2 kg^{-1}) of a sample using Formula 1.

$$PV\ (meqO_2\ kg{-}^{1}) = \frac{T\ x\ N}{W} \times 1000, \quad (1)$$

where
T − ml of the titre used.
N − normality of the titre solution.
W − sample weight.

Thiobarbituric acid reactive substances

This test was estimated by the colourimetric procedure used by Sharma *et al.* (2017b), with suitable modifications. A chicken meat patties sample was blended using a commercial blender and then two grams of the blended meat sample was mixed with

2 ml of a 30% (v/v) trichloroacetic acid solution containing 8 ml of phosphate buffer solution at pH 7. The resulting mixture was homogenized and then filtered into a volumetric flask and made up to 25 ml with distilled water. Then, a 3 ml aliquot of the filtrate was transferred into test tubes containing an equal volume of 2–thiobarbituric acid reagent (0.005 M). Tubes were heated at 80 °C for 35 min, followed by cooling in a cold-water bath (10 °C) for 10 min. The absorbance was determined at 532 nm using UV-VIS spectrophotometer, and TBARS value was calculated according to Formula 2.

$$\text{TBARS, mg MDA kg}^{-1} = (\text{Abs.} \times 5.2), \quad (2)$$

where
Abs. − sample absorbance value.
MDA − malonaldehyde.

Free fatty acid

FFA value was measured according to the procedure suggested by Kalem *et al.* (2018). 25 g of the chicken patty was dissolved in 137 ml of chloroform solvent under stirring in the presence of anhydrous sodium sulphate. The resultant was filtered by Whatman filter paper to obtain the chicken particles' free filtrate. Five drops of ethanolic phenolphthalein indicator (1%) were mixed with filtrate. Before titration, with 1 N potassium hydroxide (KOH) until the pink colour appears. FFA was computed and expressed as seen in Formula 3.

$$\text{FFA, \%} = \frac{(\text{A} \times \text{N} \times 28.2)}{\text{W}}, \quad (3)$$

where
A − ml of titre consumed.
N − normality of titre consumed.
W − weight of the sample.

pH

For pH estimation in the chicken patties, a 5 g sample was homogenized in 20 ml of distilled water using a blender (Waring Commercial Blendor®, USA) for 5 min. A standardized pH meter was used for analysis (Nardoia *et al.*, 2018).

Microbiological analyses

Microbiological analyses were evaluated according to the methodologies described by Harrigan and McCance (1976). For that, a 25 g aliquot of the chicken patties was blended with 225 ml 0.1% peptone water (Oxoid, UK) under sterile conditions, to obtain 1:10 dilution. Serial dilutions were prepared and 0.1 ml from appropriate dilutions were plated in triplicate on the specific media as follows: the total aerobic and psychrophilic bacteria were counted on nutrient agar (Hi Media, Mumbai, India), after incubation at 37 °C for 72 h and at 7 °C for 7 days, respectively. The average number of colonies was computed and multiplied by the reciprocal of dilution; the results were given as the log number of colony-forming units per gram of chicken patty (log10 cfu g^{-1}).

Statistical analysis

The effects of type extract (three different plant peel extracts) and storage time as main experiment factors were analyzed, and data were subjected to analysis of variance (ANOVA) by using SAS (Proc. GLM, SAS program, version 9.3, SAS Institute, 2012). Statistical differences among least-square means were tested with Duncan's multiple comparison *post-hoc* test. Statistically significant differences were considered at $P < 0.05$. All the determinations were conducted in triplicate.

Results and Discussion

Table 2 shows changes in peroxide (PV) values of various chicken patties samples during the frozen storage period. At zero-day storage, the initial value of PV of the control was the same in other treated samples 0.73 meq kg^{-1}. The chicken patty formulations exhibited PV values varying from 0.73 to 6.97 meq kg^{-1}. The greatest value was found to be in control as 6.97 meq kg^{-1}. On storage period 60 days, POMPEP and POTPEP and APPPEP had significantly lower PV values ($P < 0.05$), than the Control. This research shows that the inclusion of plant peel extracts in meat products slows down the oxidation process. There were significant differences ($P < 0.05$) among POMPEP and POTPEP and APPPEP in the last time of storage. Antioxidant effect of POMPEP, POTPEP and APPPEP due to their polyphenolic compounds, which prevent the formation of free radicals, and then delay the onset of the autooxidation in chicken patties (Akarpat *et al.*, 2008). Our findings were in accordance with Turgut *et al.* (2017), Shahamirian *et al.* (2019) and Haque *et al.* (2020).

Table 2. Effect of POMPEP, POTPEP and APPPEP (1%) on peroxide value of chicken patties during storage at −18 °C for 60 days

Type of extract	Peroxide value, meq kg^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.73 ± 0.08^{Ae}	3.09 ± 0.10^{Ad}	4.64 ± 0.12^{Ac}	6.53 ± 0.03^{Ab}	6.97 ± 0.05^{Aa}
T2	0.73 ± 0.04^{Ae}	2.06 ± 0.07^{Cd}	3.06 ± 0.10^{Cc}	4.85 ± 0.05^{Db}	5.10 ± 0.13^{Da}
T3	0.73 ± 0.02^{Ae}	2.62 ± 0.03^{Bd}	3.44 ± 0.04^{Bc}	5.61 ± 0.11^{Bb}	6.02 ± 0.03^{Ba}
T4	0.73 ± 0.03^{Ae}	2.20 ± 0.22^{Cd}	3.17 ± 0.06^{Cc}	5.16 ± 0.09^{Cb}	5.47 ± 0.07^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Changes in TBARS values throughout storage at −18 °C for 60 days are shown in Table 3. The changes in TBARS readings of the remaining formulations except for the control sample followed a similar trend. Extract free chicken patties sample (Control) had the maximum TBARS values 2.738 mg MDA kg^{-1}, whereas POMPEP infused chicken patties had the minimum TBARS value 0.484 mg MDA kg^{-1}.

Table 3. Effect of POMPEP, POTPEP and APPPEP (1%) on TBARS of chicken patties during storage at −18 °C for 60 days

Type of extract	TBARS, mg MDA kg^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.421 ± 0.003^{Ae}	1.045 ± 0.009^{Ad}	1.591 ± 0.003^{Ac}	2.636 ± 0.005^{Ab}	2.738 ± 0.008^{Aa}
T2	0.421 ± 0.005^{Ae}	0.484 ± 0.005^{Dd}	0.679 ± 0.002^{Dc}	1.006 ± 0.007^{Db}	1.201 ± 0.004^{Da}
T3	0.421 ± 0.005^{Ae}	0.733 ± 0.009^{Bd}	1.037 ± 0.006^{Bc}	1.544 ± 0.003^{Bb}	1.739 ± 0.005^{Ba}
T4	0.421 ± 0.004^{Ae}	0.593 ± 0.008^{Cd}	0.741 ± 0.009^{Cc}	1.162 ± 0.016^{Cb}	1.357 ± 0.003^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

The reduction percentage of TBARS on chicken meat samples containing three different extracts was expressed as 56.14% in T2, 36.49% in T3 and 50.44% in T4 at the end of the duration of storage in comparison to T1. Based on these findings, POMPEP were much more effective than the other extracts in reducing the development of TBARS. Similar to our results, significantly lower TBARS during frozen storage of Shirazi thyme, cinnamon, and rosemary incorporated beef burgers were reported by Gahruie *et al.* (2017) and clove extract added beef patties by Zahid *et al.* (2020).

Effects of POMPEP, POTPEP and APPPEP on the free fatty acid values of frozen stored chicken meat patties are shown in Table 4. The results exhibited that the lowest initial FFA value found in the T2 and T4 (0.22%, (P <0.05)), whereas the highest initial FFA value (0.37%), found in the T1 (P <0.05). The FFA values of chicken meat samples gradually increased with extended storage days, with POMPEP-treated meat having the lowest value (P <0.05) at 60 days of frozen storage. This increase could be the result of lipid gradually oxidizing during storage (Baker *et al.*, 2013; Reddy, 2017).

Table 4. Effect of POMPEP, POTPEP and APPPEP (1%) on free fatty acids of chicken patties during storage at −18 °C for 60 days

Type of extract	Free fatty acids, %				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.37 ± 0.113^{Ae}	0.70 ± 0.026^{Ad}	0.93 ± 0.026^{Ac}	1.06 ± 0.072^{Ab}	1.25 ± 0.062^{Aa}
T2	0.22 ± 0.095^{Ab}	0.27 ± 0.062^{Bb}	0.35 ± 0.070^{Cb}	0.49 ± 0.070^{Ca}	0.58 ± 0.036^{Ca}
T3	0.29 ± 0.079^{Ac}	0.39 ± 0.098^{Bc}	0.56 ± 0.056^{Bb}	0.67 ± 0.078^{Bb}	0.82 ± 0.020^{Ba}
T4	0.22 ± 0.046^{Ac}	0.29 ± 0.096^{Bc}	0.40 ± 0.036^{Cb}	0.53 ± 0.036^{Ca}	0.60 ± 0.020^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

pH values of chicken patties formulations are displayed in Table 5. All chicken patties samples had pH values ranging from 6.46 to 6.64 initially before frozen storage. The pH values of chicken patties with different treatments declined slightly within the storage period. The bacterial activity during thawing, which consumes sugar and produces acids, may be responsible for the reduction in pH levels during frozen storage (Gahruie *et al.*, 2017). At any storage time intervals at −18 °C, the pH values of chicken patties samples with POMPEP and APPPEP differed significantly (P <0.05) from control (Table 5). The results agreed with Özer *et al.* (2018) in mechanically deboned chicken patties and Haque *et al.* (2020) in beef muscle.

Table 5. Effect of POMPEP, POTPEP and APPPEP (1%) on pH of chicken patties during storage at −18 °C for 60 days

Type of extract	pH				
	Frozen storage period, day				
	0	15	30	45	60
T1	6.64 ± 0.046^{Aa}	6.62 ± 0.026^{Aa}	6.61 ± 0.053^{Aa}	6.60 ± 0.044^{Aa}	6.58 ± 0.085^{Aa}
T2	6.46 ± 0.070^{Ba}	6.45 ± 0.061^{Ca}	6.45 ± 0.053^{Ba}	6.44 ± 0.036^{Ba}	6.42 ± 0.036^{Ba}
T3	6.55 ± 0.020^{Aba}	6.53 ± 0.017^{Ba}	6.53 ± 0.026^{ABa}	6.52 ± 0.053^{ABa}	6.50 ± 0.017^{ABa}
T4	6.51 ± 0.062^{Ba}	6.50 ± 0.020^{BCa}	6.49 ± 0.075^{Ba}	6.49 ± 0.070^{Ba}	6.46 ± 0.052^{Ba}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Number of total aerobic (TAB) and psychrophilic bacteria (PSB) as $\log_{10}$ cfu g^{-1} in chicken meat patties samples during storage for 60 days at −18 °C conditions are presented in Tables 6 and 7, respectively. TAB and PSB counts were found in freshly made chicken patties before freezing to be 3.52 ± 0.070 and 0 ± 0, respectively. Low initial TAB counts and the absence of PSB in the sample could be due to sanitary processing techniques and the antibacterial roles of plant peel extracts (Sharma *et al.*, 2017a; Shahamirian *et al.*, 2019).

On the 0 day of the frozen storage period, there were no significant differences (P >0.05) in TAB and PSB counts among the chicken patty samples. TAB and PSB increased during storage while POMPEP, POTPEP, and APPPEP antibacterial characteristics were confirmed. In comparison to the control T1, patties that contained extract had the lowest TAB and PSB at the end of the storage period. The presence of polyphenols, which have an antimicrobial effect by reacting with sulfhydryl groups in proteins and rendering them inaccessible to microbes, could explain the antibacterial activity (Wolfe, Liu, 2003; Hayrapetyan *et al.*, 2012; Akyol *et al.*, 2016). In general, the reduction in number of both TAB and PSB with meat patties containing added natural antibacterials throughout frozen storage is mainly due to the

presence of polyphenolic compounds in considerable amounts. Antimicrobial activity of those compounds has included many mechanisms such as denaturation of enzymes, chelating with carbohydrates, vitamins, and minerals, changing the structure and function of the bacterial membrane (Hayrapetyan *et al.*, 2012; Baker *et al.*, 2013).

Table 6. Effect of POMPEP, POTPEP and APPPEP (1%) on Total aerobic bacteria count counts of chicken patties during storage at −18 °C for 60 days

Type of extract	Total aerobic bacteria count, log10 cfu g^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	3.52 ± 0.070^{Ae}	3.87 ± 0.036^{Ad}	4.10 ± 0.030^{Ac}	4.60 ± 0.070^{Ab}	4.71 ± 036^{Aa}
T2	3.52 ± 0.070^{Ac}	3.62 ± 0.096^{Bc}	3.80 ± 0.082^{Bb}	3.99 ± 0.017^{Ba}	4.01 ± 0.085^{Ba}
T3	3.52 ± 0.044^{Ad}	3.69 ± 0.095^{Bc}	3.82 ± 0.035^{Bb}	4.07 ± 0.053^{Ba}	4.11 ± 0.026^{Ba}
T4	3.52 ± 0.035^{Ac}	3.66 ± 0.053^{Bbc}	3.82 ± 0.106^{Bab}	4.00 ± 0.234^{Ba}	4.04 ± 0.078^{Ba}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Table 7. Effect of POMPEP, POTPEP and APPPEP (1%) on psychrophilic bacteria count counts of chicken patties during storage at −18 °C for 60 days

Type of extract	Psychrophilic bacteria count, $\log_{10}$ cfu g^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0 ± 0^{Ae}	1.37 ± 0.061^{Ad}	1.62 ± 0.108^{Ac}	2.09 ± 0.079^{Ab}	2.36 ± 0.030^{Aa}
T2	0 ± 0^{Ad}	1.15 ± 0.056^{Bc}	1.24 ± 0.050^{Bc}	1.49 ± 0.072^{Cb}	1.59 ± 0.061^{Da}
T3	0 ± 0^{Ad}	1.27 ± 0.139^{ABc}	1.39 ± 0.104^{Bc}	1.80 ± 0.140^{Bb}	2.00 ± 0.060^{Ba}
T4	0 ± 0^{Ae}	1.20 ± 0.035^{Bd}	1.31 ± 0.026^{Bc}	1.66 ± 0.044^{BCb}	1.81 ± 0.106^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Conclusion

Fruit processing operations waste different plant parts such as peel, containing important antioxidant and antibacterial compounds (polyphenols). These compounds can be used for extraction and extract can be used on meat products to improve products storability. The inclusion of alcoholic extracts of pomegranate, potato, and apple peels at a 1% ratio to chicken patties formulations stored under frozen conditions minimized oxidetive changes of lipids as significantly lowered physicochemical parameters (PV, TBARS, FFA, pH). Moreover, those extracts had a significant inhibition effect against bacterial growth.

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Conflict of interest

The authors declare that they have no conflict of interest relating to the publication of this research work.

Author contributions

EAT 50%, OHA-J 50% − study conception and design;
EAT 50%, OHA-J 50% − acquisition of data;
EAT 50%, OHA-J 50% − analysis interpretation, writing, and approval of the final manuscript.

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