Food Science of Animal Resources

Food Sci. Anim. Resour. 2020 May 40(3):388~400
DOI https://doi.org/10.5851/kosfa.2020.e19

pISSN : 2636-0772 eISSN : 2636-0780
http://www.kosfaj.org

ARTICLE

Effect of Incorporation of Pomegranate Peel and Bagasse Powder and Their Extracts on Quality Characteristics of Chicken Meat Patties

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OPEN ACCESS

Received November 20, 2019
Revised February 9, 2020
Accepted February 24, 2020

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Abstract This study was conducted to develop chicken meat patties by incorporating pomegranate peel and bagasse powders and their extracts. Patties were developed by incorporating pomegranate peel powder (PPP, 2 g), pomegranate aril bagasse powder (PABP, 4 g), pomegranate peel powder aqueous extract (PPAE, 6 g) and pomegranate aril bagasse powder aqueous extract (PABAE, 9 g) individually per 100 g of minced meat. Both types of powders and extracts treated patties had significantly higher total phenolic content than control and butylated hydroxytoluene (BHT) treated patties. Both types of powder (PPP and PABP) treated patties had significantly higher water holding capacity, ash, crude fibre content, and hardness values, and significantly lower moisture content and lightness values in comparison to control patties. Emulsion stability and cooking yield of PABP treated patties were significantly higher than control. Addition of extracts and BHT did not influence the physico-chemical properties and proximate composition of chicken patties. Both types of powders and extracts provided better protection to chicken meat patties against oxidative rancidity and microbial proliferation in comparison to control and BHT treated patties during refrigerated storage. It is concluded that pomegranate fruit byproducts in the form of peel powder, aril bagasse powder and their extracts can be successfully utilised in development of healthier chicken meat patties and these byproducts can also be effectively used as a replacement of synthetic antioxidants such as BHT.

Keywords pomegranate peel powder, pomegranate aril bagasse powder, antioxidants, aqueous extract, chicken patties

Introduction

The function of diet in the avoidance and treatment of various diseases has been extensively acknowledged. The idea of functional foods is attaining recognition nowadays as consumers are trying to improve their health by natural means. It has been observed that such foods promote one or more functions in the body apart from regular dietary effects. Studies related to development of healthier and functional meat and meat products would prove beneficial to the meat industry and eventually the consumers as the relation involving diet and chronic disease avoidance continues to rise (Kandeepan et al., 2007).

Meat and its products supply good quality proteins, essential fatty acids, minerals, vitamins, and additional nutrients, but they are deficient in dietary fibre. Consistent eating of meat products is being linked with a range of health problems like colon cancer, obesity, and cardiovascular ailments (Larsson and Wolk, 2006; Tarrant, 1998).

Lipid oxidation, autoxidation, and microbial proliferation are the main reasons for quality decline in meat and meat products. Changes in poultry meat due to oxidative rancidity may differ considerably from slight decrease in freshness to considerable flavour changes, colour losses, and structural degradation of proteins. Rancidity process is started due to vulnerability to the enzyme lypoxygenase, metalloprotein catalysts, heat, ionizing radiation, light, and metal ions (Daker et al., 2008). Meat processing procedures like mincing and cooking distort membranes of muscle cells promoting the interaction of unsaturated lipids with prooxidant substances like non-haem iron. This escalates lipid oxidation resulting in rancidity which deteriorates the quality of meat products (Tichivangana and Morrissey, 1985).

Synthetic antioxidants have been used in meat and poultry products to inhibit lipid oxidation. But they have come under watch because of their possible toxicological effects (Naveena et al., 2008; Nuñez de Gonzalez et al., 2008). Therefore, significance of natural source of antioxidants for application in meat products has increased in recent years.

Pomegranate peel and pomegranate seed/aril bagasse are main byproducts of pomegranate juice industry (Jalal et al., 2018). Pomegranate peel is major source of bioactive compounds like phenolics, flavonoids, ellagitannins, and proanthocyanidin compounds. Antioxidant and antibacterial quality of peel of pomegranate in in-vitro experimental models have been documented. Pomegranate peel extracts curb the growth of many food borne pathogens (Agourram et al., 2013; Al-Zoreky, 2009). Pomegranate seed/bagasse have a variety of nutraceutical compounds like sterols, γ-tocopherol, punicic acid, and hydroxyl benzoic acids (Liu et al., 2009). Pomegranate seed extracts exhibited antidiarrheal and antioxidant bioactivities (Singh et al., 2002). Bhol and Bosco (2013) found that pomegranate aril bagasse and pomegranate whole fruit bagasse are rich source of dietary fibre. Due to presence of valuable pharmaceutical and nutritional compounds, these byproducts can be better utilized in food industry in place of being exploited as feed for animals or marketable cosmetic products (Liu et al., 2009).

Poultry industry is attaining more significance worldwide in present times due to its better consumer recognition and freedom from religious hindrances. Huge growth of fast food market has escalated ready to eat snack foods demand. Chicken patty is one of the favourite comminuted products which have a noticeable position because of its distinctive flavour and palatability (Raut et al., 2011). In light of above information, this study was undertaken to develop chicken meat patties by incorporating powder and aqueous extracts of pomegranate peel and aril bagasse, and study the effect of their addition on quality characteristics and shelf life of developed products.

Materials and Methods

Preparation of pomegranate peel and bagasse powder and their extracts

Pomegranate peels were collected from local market juice shop. Pomegranate aril bagasse was obtained after extraction of juice from pomegranate fruit. Both the byproducts were separately washed with clean water. They were squeezed through muslin cloth to remove extra water and dried in hot air drier at a temperature of about 50℃–55℃ for about 2 d. After complete drying, both the dried products were ground to fine powder in a grinder, packed in polythene bags separately and stored at −18±2℃ for further use.

For preparing extracts, 10 g of each type of dried powder was mixed in 100 mL of distilled water separately. Both the mixtures were incubated for overnight at room temperature. Each type of mixture was filtered through muslin cloth and the filtrate was retained for use in chicken meat patties. Fresh extracts were prepared each time for use during product development and test procedures.

Slaughtering and dressing of chicken

Birds were slaughtered and dressed following the established procedure in the experimental slaughter house of the Department. The dressed chickens were deboned manually, washed and packaged in low density polyethylene bags and stored at −18±2℃ till further use. The frozen meat chunks were drawn according to necessity and thawed overnight in a refrigerator (4±2℃) for further use.

Preparation of control and treated meat patties

Deboned frozen meat was cut into small pieces and minced in an electrical mincer (3 mm plate) (Mado Primus Meat Mincer MEW-613, Dr. Froeb India Pvt., Noida, India). In control meat patties, 100 g of minced meat was taken to which sodium chloride, sodium tripolyphosphate, sodium nitrite, spice mix, condiments (ginger and garlic in ratio of 1:1), bread crumbs, water, egg liquid, and fat were added in suitable proportion (Table 1) and blended with the minced meat in a mixer (Select 600; Morphyrichards food processor, Mumbai, India) for 4 to 5 min. Treatments consisted of addition of butylated hydroxytoluene (BHT), pomegranate peel and bagasse powder and their aqueous extracts separately to minced meat. Approximately 60 g of meat emulsion was hand moulded into patty shape using a petri dish. Patties were prepared by baking

Table 1. Composition of meat emulsion for preparation of chicken meat patties

Ingredients	Treatments					
	Control	BHT	PPP	PABP	PPAE	PABAE
Meat	100	100	100	100	100	100
Sodium tripolyphosphate	0.4	0.4	0.4	0.4	0.4	0.4
Sodium chloride	1.9	1.9	1.9	1.9	1.9	1.9
Spice mix	2.0	2.0	2.0	2.0	2.0	2.0
Condiments (Ginger: Garlic) 1:1	3	3	3	3	3	3
Fat	15	15	15	15	15	15
Egg liquid	5	5	5	5	5	5
Water	10	10	10	10	10	10
Sodium nitrite	0.015	0.015	0.015	0.015	0.015	0.015
Bread crumbs	2	2	2	2	2	2
Butylated hydroxytoluene	-	0.01	-	-	-	-
Dried pomegranate peel powder	-	-	2	-	-	-
Dried pomegranate aril bagasse powder	-	-	-	4	-	-
Dried pomegranate peel powder aqueous extract	-	-	-	-	6	-
Dried pomegranate aril bagasse powder aqueous extract	-	-	-	-	-	9

Chicken meat patties incorporated with 2 g dried pomegranate peel powder (PPP), 4 g dried pomegranate aril baggase powder (PABP), 6 g dried pomegranate peel powder aqueous extract (PPAE) and 9 g dried pomegranate aril bagasse powder aqueous extract (PABAE), respectively.
BHT, butylated hydroxytoluene.

in a preheated oven at a temperature of 160℃ for 35 min (20 min first side and 15 min second side). Both control and treated patties were packaged in low density polythene bags and subjected to physico-chemical, nutritional, instrumental colour, and texture analysis. Patties were also stored under refrigerated storage (4±2℃) conditions and physico-chemical and microbiological quality of the products were analysed at a regular interval of 4 d upto 16 d of storage.

Total phenolic content

Folin Ciocalteu's technique was followed to determine total phenolic content. Absorbance was measured at 750 nm by UV visible spectrophotometer (G 10 S UV-VIS; Thermo Fisher Scientific India Pvt., Mumbai, India). For standard, gallic acid was used and results were calculated as mg of gallic acid equivalent (GAE)/100 g of dry mass (Bhalodia et al., 2011).

Physico-chemical parameters

The pH of chicken patties was estimated with pH meter (Cyber Scan pH 510; Eutech Instruments, Thermo Fisher Scientific India Pvt., Mumbai, India) following the procedure of Trout et al. (1992). Control and treated emulsions stability were estimated using the method of Baliga and Madaiah (1970). For cooking yield, the weight of raw and cooked patties was measured and yield was expressed as percentage. Water holding capacity (WHC) was determined as per the procedure of Wardlaw et al. (1973). Thiobarbituric acid (TBA) value of patties was estimated as per the method of Witte et al. (1970). Trichloroacetic acid extract of meat samples was mixed with TBA reagent. The contents were placed in boiling water bath and optical density was determined at 540 nm. TBA value was calculated as mg malonaldehyde/kg of sample.

Proximate composition

Moisture, protein, fat, ash, and crude fibre content of chicken meat patties were estimated by standard procedure of AOAC (2005). Finally chopped sample of meat was dried in hot air oven (JSGW, Ambala, India), cooled in desiccator and loss in weight was expressed as moisture content of the sample. Protein was estimated using Kjeldahl digestion method. The fat content of samples was determined by solvent extraction method using petroleum ether (60℃ to 80℃) as solvent. Ashing was done in a muffle furnace (Yorco, Yorco sales Pvt., New Delhi, India) set at 550℃ to determine ash content of samples. For crude fibre content, fat free samples were subjected to acid and alkali digestion. The residue remaining after digestion was weighed and subjected to ashing. Difference in weight was calculated as crude fibre.

Texture profile analysis

The textural properties of patties were evaluated by the method of Bourne (1978) using TA.HD plus twin column texture analyser (Stable Micro Systems, Godalming, UK) equipped with the exponent software (version 5,1,1,0 Lite).

Samples of 2 cm^3 size were compressed (by 70 mm compression plate, 50 kg load cell and the test speed of 2 mm/s) to 50% of their initial height. Between two compression cycles, 5 s time interval was given to obtain force time deformation curves. Hardness (N), cohesiveness, springiness, gumminess (N), and chewiness (N) of the samples were analyzed.

Firmness and toughness

The force required to shear a 1cm^3 thick sample of cooked chicken meat patties transversely was analysed using Warner-Bratzler shear probe of texture analyser (TA.HD plus, Stable Micro Systems). A force time curve was obtained. Firmness (N) was the maximum shear force required to cut the sample. Toughness (N-s) was the total shear energy (i.e. work of shear) calculated as the area under force time curve from start to the end of the shear test.

Instrumental colour analysis

The colour scores of chicken patties were measured as CIE Lab, L* (lightness), a* (redness), and b* (yellowness) using a chroma meter (Konica Minolta Sensing, Osaka, Japan) with 8 mm orifice for measurement. The equipment was standardized with a white standard plate before measurement.

Microbiological evaluation

Total plate count (TPC), psychrotrophic, and thermophilic counts of chicken patties were estimated during refrigerated storage (APHA, 2001).

Statistical analysis

The data acquired were evaluated by analysis of variance. For fresh products, one-way analysis of variance and for refrigerated stored products, two-way analysis of variance were performed. Duncan's test was performed using SPSS version 16 (SPSS, Chicago, IL, USA) to determine the significant difference in the mean values at 5% significance level.

Results and Discussion

Total phenolic content

A small quantity of phenolic compounds were observed in control raw emulsion and patties which was due to polyphenols provided by spices and condiments added to chicken meat emulsion (Table 2). Polyphenolic content and antioxidant capacity of different spices have been well established (Pellegrini et al., 2006; Zheng and Wang, 2001). Addition of BHT, pomegranate peel and bagasse and their extracts to chicken meat resulted in an appreciable increase in total phenolic content. Also, pomegranate by products and their extracts treated patties had significantly higher phenolic content than BHT treated

Table 2. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on total phenolic content and physico-chemical properties of chicken meat emulsion and patties

Treatments	Total phenols (raw) (mg GAE/g)	Total phenols (cooked) (mg GAE/g)	pH (raw emulsion)	pH (cooked)	Water holding capacity (%)	Emulsion stability (%)	Cooking yield (%)
Control	0.11±0.04^{e}	0.12±0.07^{e}	6.13±0.06^{a}	6.30±0.10^{a}	43.60±1.42^{c}	92.56±0.77^{b}	83.65±0.69^{b}
BHT	0.27±0.06^{d}	0.28±0.04^{d}	6.10±0.10^{a}	6.25±0.08^{a}	44.13±1.94^{bc}	93.40±1.47^{b}	83.36±2.37^{b}
PPP	1.36±0.19^{a}	1.49±0.08^{a}	6.07±0.13^{a}	6.21±0.14^{a}	46.24±1.16^{b}	93.78±1.28^{b}	85.37±2.70^{ab}
PABP	0.84±0.06^{b}	0.88±0.02^{b}	6.09±0.06^{a}	6.23±0.09^{a}	48.78±2.12^{a}	95.00±0.47^{a}	86.03±1.50^{a}
PPAE	0.88±0.07^{b}	0.91±0.06^{b}	6.07±0.10^{a}	6.23±0.12^{a}	44.15±2.20^{bc}	92.98±0.77^{b}	84.15±1.58^{ab}
PABAE	0.66±0.12^{c}	0.69±0.15^{c}	6.08±0.08^{a}	6.24±0.10^{a}	44.36±1.49^{bc}	93.62±0.87^{b}	84.20±0.77^{ab}

n=6, Mean±SD.
Means with different superscripts in a column differ significantly ($p<0.05$).
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.

patties. Pomegranate peel powder (PPP) treatment had significantly higher phenolic content in comparison to pomegranate aril bagasse powder (PABP) treatments. Similarly, peel extract treated emulsion and patties had significantly higher phenolic content than bagasse extract treated emulsion and patties, respectively. Higher phenolic content in peel treated emulsion and patties in comparison to bagasse treated emulsion and patties was due to higher total phenolic content in PPP (52.3 mg GAE/g) in comparison to PABP (30.1 mg GAE/g). A number of research workers have demonstrated higher phenolic content in pomegranate peel in comparison to its pulp and bagasse. Findings of present research work are in agreement with previous studies. Li et al. (2006) revealed that peel tissues of pomegranate normally contain higher quantity of phenolics than its pulp. Sultana et al. (2008) reported that total phenol and total flavonoid content of PPP were higher in comparison to pomegranate aril bagasse and whole fruit bagasse powder. Devatkal and Naveena (2010) also reported higher total phenolic content in pomegranate rind powder (PRP) in comparison to pomegranate seed powder (PSP). Within a particular byproduct, powder treatment had higher phenolic content in comparison to respective extract treatment. Higher amount of phenolics in powder treated emulsion and patties in comparison to respective extract treated emulsion and patties might be due to less extraction of phenolics in aqueous extract. Separation of phenolic compounds from their innate structure is complex due to their heterogenicity and vulnerability to oxidation and hydrolysis (Naczk and Shahidi, 2004). Kind of solvent, proportion of solid to liquid, extraction temperature, and peel particles size significantly affect antioxidant extraction (Ismail et al., 2012).

Physico-chemical qualities of chicken meat emulsion and patties

The pH of raw emulsion and cooked chicken patties did not vary significantly between control and treatments, although a non-significantly lower pH was noticed in pomegranate byproducts and their extract incorporated patties (Table 2). WHC increased significantly in pomegranate by products i.e. PPP and PABP incorporated patties in comparison to control. PABP treated patties had significantly highest WHC value among all treatments. Higher WHC in PPP and PABP treated patties might be due to presence of dietary fibre in pomegranate peel and bagasse powder which has been reported to increase the WHC (Cofrades et al., 2000). Viuda-Martos et al. (2012) reported that pomegranate bagasse powder co-product exhibited WHC equal to 4.86 times of its own weight. Akhtar et al. (2015) found that incorporation of 3% PRP in raw beef sausage improved their WHC.

Emulsion stability and cooking yield of PABP treated patties was significantly higher than control. As discussed earlier, higher cooking yield of PABP treated patties was due to presence of dietary fibres which increases cooking yield because of their water and fat binding attributes (Cofrades et al., 2000). PPP treated patties also had dietary fibre, but it did not result in significant increase in cooking yield, although a non-significantly higher yield than control was observed in PPP treated patties. This might be due to lower level of PPP used in patties. Abdel Fattah et al. (2016) also reported better cooking yield in beef burgers incorporated with PPP. Addition of BHT and pomegranate by product aqueous extracts (pomegranate peel powder aqueous extract [PPAE] and pomegranate aril bagasse powder aqueous extract [PABAE]) did not result in any significant effect on WHC, emulsion stability, and cooking yield of chicken meat patties.

Proximate composition

Addition of pomegranate peel and aril bagasse powder contributed to significant decline in moisture content of patties (Table 3). This was due to replacement of meat with dried peel and aril bagasse containing very low moisture. The moisture content of dried peel powder and dried aril bagasse powder was 11.06% and 5.55%, respectively. El-Nashi et al. (2015) revealed that addition of PPP to beef sausage contributed to significant decline in moisture content. Powder treated patties

Table 3. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on proximate composition of chicken meat patties

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)
Control	60.08±0.97^{a}	17.08±0.80^{a}	16.58±0.39^{b}	1.73±0.24^{b}	0.26±0.13^{c}
BHT	60.06±0.99^{a}	16.76±0.99^{a}	16.68±0.56^{b}	1.70±0.12^{b}	0.29±0.11^{c}
PPP	58.61±1.21^{bc}	16.61±0.95^{a}	17.04±0.75^{ab}	2.10±0.15^{a}	0.60±0.10^{b}
PABP	57.64±1.20^{c}	17.15±1.36^{a}	17.60±0.57^{a}	2.15±0.14^{a}	1.58±0.10^{a}
PPAE	59.93±0.99^{a}	16.89±1.18^{a}	16.83±0.88^{ab}	1.84±0.18^{ab}	0.34±0.08^{c}
PABAE	59.74±0.85^{ab}	16.33±0.63^{a}	16.96±0.63^{ab}	1.85±0.26^{ab}	0.35±0.08^{c}

n=6, Mean±SD.
Means with different superscripts in a column differ significantly ($p<0.05$).
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.
Moisture, crude fat, crude protein, crude fibre and ash content for pomegranate fruit peel powder were 11.03%, 1.42%, 6.83%, 15.80%, respectively.
Moisture, crude fat, crude protein, crude fibre and ash content for pomegranate aril bagasse powder were 5.55%, 5.38%, 16.86%, 17.42%, 32.32%, and 3.22%, respectively.

had significantly lower moisture content in comparison to respective extract treated patties.

Protein content of control and treated patties did not varied remarkably. Addition of pomegranate aril bagasse powder contributed to significant increase in fat content and treatment PABP had significantly higher fat content than control. Higher fat content in PABP treated patties was due to more retention of fat and presence of higher amount of fat in pomegranate aril bagasse powder (16.86%). Earlier, Özgül-Yücel (2005) revealed that pomegranate seeds are a plentiful source of total lipids. Ash content of pomegranate peel and bagasse powder treated patties was significantly higher in comparison to control which was due to higher ash content in PPP (4.03%) and PABP (3.22%). A small quantity of crude fibre was observed in control chicken patties which was attributable to dietary fibre provided by spices and condiments incorporated in raw emulsion. A significant increase in crude fibre content in PPP and PABP patties was observed which was because of higher crude fibre content in pomegranate peel and aril bagasse powder. PABP patties also had significantly higher crude fibre content in comparison to PPP patties. This was due to more amount of PABP (4 g) incorporated in chicken meat in comparison to PPP (2 g). Also, higher amount of crude fibre in PABP (32.32%) in comparison to PPP (15.80%) contributed to significantly higher crude fibre content in PABP treated patties. Rowayshed et al. (2013) revealed that the PPP and PSP are considered as good source of crude fibre. Bhol and Bosco (2013) observed a substantial increase in fibre content in bread with rise in level of pomegranate bagasse powder. Addition of BHT, PPAE, and PABAE did not influence the proximate composition of chicken patties.

Instrumental colour analysis

Incorporation of pomegranate by products and their extracts contributed to a decline in lightness and significant decline in relation to control was noticed in PPP and PABP treated patties (Table 4). Significant decrease in lightness in these treatments might be due to dark colour contributed by pomegranate peel and bagasse. González and Enríquez (1994) reported that colour is influenced by various factors, but drying process in particular influence the colour. Pulp is exposed to high temperature during its drying, which leads to enzymatic and non-enzymatic browning resulting in darkening of the product. Addition of BHT, powders, and extracts did not influence the redness and yellowness values of chicken patties.

Table 4. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on instrumental colour analysis of chicken meat patties

Treatments	Lightness (L*)	Redness (a*)	Yellowness (b*)
Control	56.46±1.09^{a}	4.05±0.67^{a}	11.84±0.93^{a}
BHT	55.49±0.64^{a}	4.47±0.44^{a}	11.87±0.50^{a}
PPP	50.08±3.07^{b}	4.58±0.74^{a}	11.14±0.35^{a}
PABP	51.35±4.55^{b}	4.76±0.40^{a}	11.06±1.09^{a}
PPAE	52.03±2.06^{ab}	4.65±0.76^{a}	11.24±0.76^{a}
PABAE	52.20±2.38^{ab}	4.51±0.88^{a}	11.63±1.07^{a}

n=6, Mean±SD.
Means with different superscripts in a column differ significantly ($p<0.05$).
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.

Texture profile, firmness and toughness of chicken meat patties

Texture profile analysis of control and treated patties revealed a significant increase in hardness of PPP and PABP treated patties (Table 5). Higher hardness values in these treatments might be due to hardness and rigidity contributed by pomegranate peel and bagasse. Lower moisture content in these treatments might have contributed to higher hardness. Yadav et al. (2016) also documented an increase in hardness scores of dried apple pomace added chicken sausage. PPP patties had significantly higher hardness than PABP treated patties. Gumminess score of PPP treated patties were significantly higher in comparison to control, which was due to their higher hardness values. Chewiness values of both the extract treated patties were significantly lower in comparison to PPP treated patties, which was due to their significantly lower hardness value and non-significantly lower springiness values. Pomegranate byproducts powder addition resulted in an increase in firmness and toughness, and significant rise in relation to control was observed in PPP incorporated patties. Addition of BHT, PPAE, and PABAE did not affect texture profile, firmness, and toughness of chicken patties.

Table 5. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on texture profile, firmness (N), and toughness (N-s) of chicken meat patties

Treatments	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)	Firmness (N)	Toughness (N-s)
Control	38.87±4.78^{c}	0.89±0.06^{a}	0.54±0.15^{a}	20.68±5.33^{b}	18.59±5.92^{ab}	8.59±1.02^{b}	52.91±3.55^{b}
BHT	39.57±3.98^{c}	0.87±0.04^{a}	0.54±0.10^{a}	21.39±3.55^{b}	18.58±3.59^{ab}	9.99±1.77^{b}	48.06±4.48^{b}
PPP	54.72±2.76^{a}	0.87±0.04^{a}	0.50±0.10^{a}	27.26±5.54^{a}	23.79±5.92^{a}	13.55±2.36^{a}	73.71±3.23^{a}
PABP	48.31±4.70^{b}	0.87±0.04^{a}	0.46±0.02^{a}	22.19±2.47^{b}	19.30±2.80^{ab}	11.33±3.35^{ab}	55.97±3.00^{b}
PPAE	37.55±3.65^{c}	0.85±0.03^{a}	0.50±0.07^{a}	18.69±3.35^{b}	15.90±3.10^{b}	10.39±2.00^{b}	50.82±5.22^{b}
PABAE	36.25±3.07^{c}	0.84±0.03^{a}	0.48±0.05^{a}	17.54±1.50^{b}	14.76±1.51^{b}	9.29±2.69^{b}	50.23±5.87^{b}

n=6, Mean±SD.
Means with different superscripts in a column differ significantly ($p<0.05$).
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.

Physico-chemical and microbiological quality of pomegranate fruit byproducts treated chicken patties during refrigerated storage

pH values

pH of control and treated patties did not vary considerably during refrigerated storage (Table 6). There was a modest decrease in pH of chicken meat patties during initial days of refrigeration. Subsequently, pH increased on 12 d and 16 d of storage. Lactic acid bacteria multiply in the beginning, which leads to disintegration of sugar into acids. Subsequently, bacterial deamination of proteins occurs which raises the pH of the product (Jay, 1996).

TBA value

TBA value of control and treated patties increased significantly during refrigerated storage. However, TBA values of PPP and PABP treated chicken patties were significantly lower than control throughout the storage period. TBA values of BHT, PPAE, and PABAE were also lower than control during storage. Significant difference was observed from 8 d onward in PPAE and PABAE treated patties and 12 d onward in BHT treated patties. Bioactive compounds like phenols and flavonoids present in pomegranate peel and bagasse provided antioxidant effect and inhibited lipid oxidation in chicken patties resulting in lower rise in TBA values in these treatments. The results indicate that pomegranate peel, bagasse, and extracts provided better protection against rise in TBA value in comparison to BHT, and can be used as natural antioxidant sources in chicken meat patties in place of synthetic antioxidants. Decrease in TBA value of meat and meat products due to antioxidant effect of

Table 6. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on pH and thiobarbituric acid (TBA) value of chicken meat patties packaged under aerobic conditions and stored at 4±2℃

Treatments	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day
pH					
Control	$6.30±0.10^{aBC}$	$6.21±0.13^{aC}$	$6.25±0.04^{aBC}$	$6.35±0.08^{aAB}$	$6.42±0.09^{aA}$
BHT	$6.25±0.08^{aBC}$	$6.14±0.09^{aC}$	$6.24±0.07^{aBC}$	$6.30±0.10^{aB}$	$6.42±0.09^{aA}$
PPP	$6.21±0.14^{aBC}$	$6.11±0.11^{aC}$	$6.20±0.08^{aBC}$	$6.27±0.06^{aAB}$	$6.36±0.09^{aA}$
PABP	$6.23±0.09^{aBC}$	$6.17±0.07^{aC}$	$6.20±0.08^{aBC}$	$6.28±0.08^{aB}$	$6.41±0.10^{aA}$
PPAE	$6.23±0.12^{aBC}$	$6.16±0.04^{aC}$	$6.23±0.09^{aBC}$	$6.28±0.07^{aAB}$	$6.39±0.11^{aA}$
PABAE	$6.24±0.10^{aB}$	$6.18±0.06^{aB}$	$6.23±0.13^{aB}$	$6.30±0.10^{aAB}$	$6.40±0.10^{aA}$
TBA value (mg malonaldehyde/kg)					
Control	$0.56±0.08^{aD}$	$0.63±0.26^{aD}$	$1.05±0.03^{aC}$	$1.64±0.27^{aB}$	$1.95±0.15^{aA}$
BHT	$0.53±0.10^{aC}$	$0.61±0.22^{abC}$	$0.87±0.04^{abB}$	$1.16±0.24^{bA}$	$1.40±0.32^{bA}$
PPP	$0.24±0.07^{cC}$	$0.35±0.10^{cC}$	$0.72±0.14^{bA}$	$0.78±0.20^{cA}$	$0.81±0.11^{cA}$
PABP	$0.30±0.10^{cB}$	$0.40±0.12^{bcB}$	$0.75±0.29^{bA}$	$0.83±0.22^{cA}$	$0.84±0.06^{cA}$
PPAE	$0.41±0.07^{bB}$	$0.50±0.07^{abcB}$	$0.75±0.27^{bA}$	$0.81±0.05^{cA}$	$0.83±0.10^{cA}$
PABAE	$0.46±0.13^{abC}$	$0.56±0.12^{abBC}$	$0.81±0.16^{bAB}$	$0.81±0.05^{cAB}$	$1.00±0.39^{cA}$

n=6, Mean±SD.
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.
Means with different small superscripts within a column and capital superscripts within a row for a particular parameter differ significantly ($p<0.05$).

pomegranate fruit byproducts, and their extracts has been reported previously by various research workers. El-Gharably and Ashoush (2011) and Naveena et al. (2008) observed that PPP improved the storage stability of meat products during refrigeration by reducing the rate of lipid oxidation. Devatkal et al. (2010) also observed a significant reduction in thiobarbituric acid reactive substances (TBARS) values of goat meat patties treated with the extracts of PRP and PSP as compared to control during refrigerated storage. Abdel Fattah et al. (2016) reported lower TBARS value in PPP incorporated beef burgers in comparison to control on 12 d of storage.

Microbiological status

TPC, psychrotrophic count, and thermophilic count of control and treated patties increased significantly with increase in storage duration in all the treatments (Table 7). The rate of increase was less in pomegranate byproducts and their extract

Table 7. Effect of pomegranate peel powder, pomegranate aril bagasse powder, and their aqueous extracts on microbial counts of chicken meat patties packaged in aerobic conditions and stored at 4±2℃

Treatments	0 day	4^{th} day	8^{th} day	12^{th} day	16^{th} day
Total plate count (Log CFU/g)					
Control	2.43±0.48^{aE}	3.46±0.56^{aD}	4.09±0.35^{aC}	5.09±0.37^{aB}	5.72±0.36^{aA}
BHT	2.51±0.22^{aD}	3.36±0.58^{aC}	3.81±0.41^{abC}	4.80±0.72^{abB}	5.46±0.59^{abA}
PPP	2.35±0.65^{aD}	2.96±0.41^{aC}	3.40±0.40^{bC}	4.07±0.49^{cB}	4.70±0.23^{cA}
PABP	2.43±0.63^{aC}	2.96±0.54^{aC}	3.60±0.55^{abB}	4.28±0.42^{bcA}	4.85±0.41^{cA}
PPAE	2.24±0.12^{aE}	3.06±0.56^{aD}	3.70±0.49^{abC}	4.51±0.46^{abcB}	5.11±0.45^{bcA}
PABAE	2.28±0.09^{aE}	3.04±0.38^{aD}	3.72±0.43^{abC}	4.60±0.55^{abcB}	5.16±0.37^{bcA}
Psychrotrophic count (Log CFU/g)					
Control	ND	1.30±0.69^{aC}	1.96±0.28^{aB}	2.51±0.57^{aAB}	3.10±0.42^{aA}
BHT	ND	1.12±0.61^{aC}	1.79±0.39^{aB}	2.46±0.63^{aB}	2.96±0.36^{aA}
PPP	ND	0.91±0.75^{aC}	1.60±0.74^{aBC}	2.08±0.41^{aAB}	2.40±0.28^{bA}
PABP	ND	1.01±0.76^{aC}	1.69±0.97^{aBC}	2.17±0.30^{aAB}	2.65±0.26^{abA}
PPAE	ND	1.02±0.37^{aD}	1.69±0.38^{aC}	2.24±0.36^{aB}	2.75±0.37^{abA}
PABAE	ND	1.13±0.67^{aC}	1.70±0.44^{aBC}	2.20±0.40^{aAB}	2.80±0.47^{abA}
Thermophilic count (Log CFU/g)					
Control	1.36±0.39^{aE}	1.98±0.31^{aD}	2.61±0.61^{aC}	3.09±0.30^{aA}	3.63±0.32^{aA}
BHT	1.23±0.54^{aC}	1.81±0.49^{aC}	2.49±0.64^{aB}	2.91±0.36^{abAB}	3.42±0.40^{abA}
PPP	1.21±0.74^{aD}	1.68±0.81^{aCD}	2.14±0.38^{aBC}	2.60±0.41^{bAB}	2.96±0.22^{cA}
PABP	1.25±0.75^{aC}	1.69±0.41^{aC}	2.37±0.58^{aB}	2.81±0.38^{abAB}	3.10±0.42^{bcA}
PPAE	1.26±0.74^{aC}	1.71±0.38^{aBC}	2.41±0.56^{aB}	2.82±0.38^{abA}	3.25±0.26^{abcA}
PABAE	1.26±0.74^{aD}	1.72±0.97^{aCD}	2.42±0.52^{aBC}	2.84±0.38^{abAB}	3.30±0.25^{abcA}

n=6, Mean±SD.
BHT, 100 ppm butylated hydroxytoluene; PPP, 2 g pomegranate peel powder; PABP, 4 g pomegranate aril bagasse powder; PPAE, 6 g pomegranate peel powder aqueous extract; PABAE, 9 g pomegranate aril bagasse powder aqueous extract.
Means with different small superscripts within a column and capital superscripts within a row for a particular parameter differ significantly ($p<0.05$).
ND, not detected.

treated patties. Inhibitory effect of bioactive and phenolic compounds present in pomegranate peel, bagasse, and their extracts resulted in significantly lower TPC in treated patties in comparison to control at the end of storage. Maximum inhibitory effect on growth of microbes was noticed in PPP treated patties resulting in significantly lowest TPC at the end of storage. PPP treated patties also had significantly lower psychrotrophic and thermophilic counts in comparison to control patties at the end of storage. Results indicate that pomegranate fruit by products such as peel, aril bagasse, and their extracts possess antimicrobial activity. Al-Zoreky (2009) observed that pomegranate extract intervened with production of bacterial proteins. Chandralekha et al. (2012) observed a significant decrease in standard plate count of 5% rind powder incorporated chicken meatball in comparison to control during refrigerated storage.

Conclusion

Incorporation of pomegranate fruit byproducts in the form of peel powder, aril bagasse powder, and their aqueous extracts improved nutritional value of chicken patties by increasing their total phenolics content. TBA values of powder and extract treated patties were lower in comparison to control and BHT treated patties during refrigerated storage. This study indicates that pomegranate fruit byproducts and their extracts can be used as a replacement of synthetic antioxidants such as butylated hydroxytoluene for development of chicken meat patties. Both the powders provided additional nutritional benefit by increasing crude fibre content of patties while bagasse powder also increased their cooking yield. Microbial counts in powder and extract treated patties were lower than control during refrigerated storage. Best antimicrobial effect was observed in PPP treated patties.

Conflicts of Interest

The authors declare no potential conflicts of interest.

Author Contributions

Conceptualization: Yadav S. Data curation: Sharma P. Formal analysis: Sharma P, Yadav S. Methodology: Sharma P. Software: Sharma P, Yadav S. Validation: Sharma P. Investigation: Sharma P. Writing - original draft: Sharma P, Yadav S. Writing - review & editing: Sharma P, Yadav S.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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