Official Journal Issued by Faculty of Veterinary Medicine

Benha Veterinary Medical Journal

Journal homepage: https://bvmj.journals.ekb.eg/

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Original Paper

The efficiency of citrus peel powders in improvement of minced beef quality during chilled storage

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ARTICLE INFO

Keywords

Lemon peel powders
Orange peel powder
Minced meat
Shelf life

Received 15/06/2022
Accepted 17/10/2022
Available On-Line 01/11/2022

ABSTRACT

The current study aimed to determine the effect of some citrus peel powders represented by lemon peel (LP) and orange peel powders (OP) by two concentrations (5% and 10% for each) on the sensory, microbiological, and chemical parameters of raw chilled minced beef at refrigerator temperature (4±1^{O}C). The obtained results showed enhanced sensory characters with significant reductions in microbial and improved chemical values ($P \leq 0.05$) in the treated samples as compared with control untreated samples along the experimental period. Lemon powder treated samples showed higher quality than those treated with orange peel powder. Although higher concentration of lemon or orange powders (10%) gave higher reduction% in microbes, it was negatively affecting the sensory characters (abundant odor and discoloration). In contrast, lower concentration of such powders (5%) result in significant bacterial reduction% and better chemical parameters without significant changes in the sensory scores. Generally, the used citrus peel powders gave add-on values to the treated minced beef samples and usage of 5% lemon peel powder is recommended as minced meat additive.

1. INTRODUCTION

High quality raw meats are valuable proteinaceous foods; rich in vitamins and minerals, however, they also contain unsaturated fatty acids which act as the key-point for acceptable and safe meat product of high nutritive value and long shelf-life (Mir *et al.*, 2017).

Improper packaging and storage conditions enhance lipid oxidation and protein putrefaction leading to unfavorable sensory changes affecting the physical quality causing shelf-life limitation of meat products (Jiménez-Colmenero *et al.*, 2012; Domínguez *et al.*, 2019).

Natural and synthetic food-additives, of the antioxidant effect, have been commonly used in meat industry to inhibit the development of oxidative reactions and extending shelf-life of meat products (Cunha *et al.*, 2018). However, consumers prefer using of natural food-additives in various products to delay oxidative degradation of lipids, improve quality and nutritional value of foods and replace synthetic preservatives (Aminzare *et al.*, 2019).

An increased attention has been directed toward plant-based additives due to the presence of high content of bioactive components in fruit-byproducts which act as antioxidants, antimicrobials, flavorings, and thickening agents (Vilas-Boas *et al.*, 2021).

Citrus is the most plentiful yield worldwide. Citrus byproducts have well as useful technical and nutritional characteristics. These compounds have shown antimicrobial effects against harmful foodborne microorganisms by lysis of them through cell membrane (Rafiq *et al.*, 2018). In addition, they are rich in dietary fibers, low cost and high value; so, their incorporation into meat products could result in benefits for human health (Silva *et al.*, 2020; Zaki and Naeem, 2021).

Peels are considered as the main citrus byproduct, accounting for around 50%-65% of the fruit's weight during processing. Antioxidant compounds such as pectin, flavonoids such as hesperidin, essential oils, and carotenoids found in citrus peels scavenge free radicals and slow or stop DNA oxidation, proteins and lipids that lead to degenerative diseases like atherosclerosis, stroke, and diabetes (Chatha *et al.*, 2011).

Fruit peels might be utilized as natural supplements in the production of meat products, not only to extend the shelf life by delaying microbial development and lipid oxidation, but also to generate low-cost, high-nutrition products with good organoleptic and physicochemical features (Nieto *et al.*, 2021).

Accordingly, the effectiveness of addition of orange (OP) or lemon peel (LP) powders (5 and 10%) on some quality properties and shelf-life of minced beef during cold storage was investigated in the present experiment.

2. MATERIAL AND METHODS

2.1. Collection of minced beef:

1500 g of fresh minced beef were purchased from different butchers' shops located in Benha city, Qalubiya governorate, Egypt. The samples were mixed, placed in a sterile plastic bag, and refrigerated in 4±1^{O}C to be examined as rapidly as possible.

2.2. Collection of citrus peels:

Ripened and freshly harvested citrus lemon (*Citrus aurantiifolia*) and orange (*Citrus sinensis*) fruits were

purchased from a local market located in Benha city, Qalubiya governorate.

2.3. Preparation of lemon and orange peels powder (Ibrahim et al., 2013):

The lemon and orange fruits were rinsed under tap water and peeled. Fresh citrus peels were sliced into small pieces, then dried for about 6 min in a microwave oven (1500W). The dried LP and OP citrus peels were crushed to a fine powder in a mechanical grinder and sieved.

2.4. Experimental design:

2.4.1. Preparation of samples

The collected minced meat samples were mixed well in a sterile condition, and divided into five equal groups (300 g/group) with the addition of citrus peel powders as follow:

G1: Control group (300 g mince beef without treatment).
G2: 300 g minced beef + LP (5%)
G3: 300 g minced beef + LP (10%)
G4: 300 g minced beef + OP (5%)
G5: 300 g minced beef + OP (10%)

Control and treated groups were refrigerated at 4±1^{O}C. Sensory, microbiological, and chemical examination were performed at day zero (within 30 min. after treatment), and then periodically every 3 days of chilled storage until sensory deterioration. The trial was repeated in triplicates.

2.4.1.1. Sensory evaluation (color, odor, texture and overall) following Mörlein (2019) in scores (1 to 5), where ≤1- represented the worst while 5- represented the excellent mark.

2.4.1.2. Microbiological profile

1. Preparation of samples (ISO 6887-2, 2017): tenfold serial dilutions were prepared on sterile peptone water (0.1%); from which the following parameters were examined by pour-plate method:

A. Aerobic plate count "APC" according to ISO 4833-1 (2013) on APC agar and incubated at 30±1^{O}C for 72h.

B. Enterobacteriaceae count "EC" according to ISO 21528-2 (2017) on VRBG agar and incubated at 37±1^{O}C for 24h.

C. *Escherichia coli* counts, according to ISO 16649-2 (2001) on TBX agar and incubated at 44±1^{O}C for 24h.

D. *Staphylococcus aureus* count (ISO 6888-1, 2003)

It was applied using Baird Parker agar supplemented with egg yolk tellurite and incubated at 35±2^{O}C for 24h.

E. Mould and yeast count (ISO 21527-1, 2008)

DRBC agar plates were used and incubated at 25±1^{O}C for 5-7 days in upright position. Any plate counted ≤5 CFU/g was ignored.

2.4.1.3. Chemical profile:

A. Total Volatile Nitrogen (TVN) was measured according to the procedure of ES: 63-9/2006.

B. Thiobarbituric Acid (TBA) was measured according to ES: 63-10/2006.

2.5. Statistical analysis:

were performed by application of Analysis of Variance (ANOVA) test on SPSS software v.20 according to Feldman *et al.* (2003).

3. RESULTS

The current study aimed to investigate the sensory, microbiological, and chemical attributes indicating the shelf life of the treated minced beef samples. Table (1) indicated that the treatment with LP and OP extended the acceptable sensory characters significantly when compared with a control group which showed spoilage signs on the 9th day of chilling storage. LP 5% showed the highest scores up to the 15th day of the experiment (3.0: acceptable), while spoilage mildly appeared at the end of the experiment in the other treated groups indicating the superiority of LP5%. Higher concentrations had lower scores because of abundant yellowish discoloration and citrus odor of the treated samples.

Table (2) declared that the treatment with LP and OP reduced APC significantly in comparison with a control group which showed spoilage signs on the 9th day of chilling storage (7.11±0.6 $\log_{10}$CFU/g). LP 10% showed the highest reduction percent after the 15th day of the experiment (35.26%) indicating a higher reduction effect with higher concentration application.

Table (3) showed that the treatment with LP and OP inhibited Enterobacteriaceae count significantly in comparison with a control group which showed spoilage signs on the 9th day of chilling storage (4.61±0.3 $\log_{10}$CFU/g). ECs were <1 CFU/g at the 15th day in G2, G4 and G5, while starts in the 9th day in the G3 indicating superiority of lemon 10% in inhibiting EC.

Table (4) revealed that the treatment with LP and OP inhibited *E. coli* count significantly in comparison with a control group which showed spoilage signs in the 9th day of chilling storage (3.89±0.4 $\log_{10}$CFU/g). *Escherichia coli* counts showed the highest reduction % in G3 that appeared <1 $\log_{10}$CFU/g at the 9th day of incubation indicating that L10% had the highest inhibitory effect on *E. coli*. In addition, G2, G4 and G5 still showed *E. coli* count until the 12th day of incubation, while all the treated samples showed absence of *E. coli* after the 15th day of incubation.

Table (5) indicated that the treatment with LP and OP inhibited *S. aureus* count significantly in comparison with a control group which showed spoilage signs in the 9th day of chilling storage (3.17±0.3 $\log_{10}$CFU/g). *Staphylococcus aureus* counts recorded <1 $\log_{10}$CFU/g after 12 days of cold storage in G2 and G4, while starts in the 9th day in the G3 and G5 with reduction percent 100% indicating higher reduction % with higher concentration of the added powder.

Table (6) showed that the treatment with LP and OP inhibited fungal growth significantly in comparison with a control group which showed spoilage signs on the 9th day of chilling storage (3.41±0.3 $\log_{10}$CFU/g). Total fungal counts were <1 $\log_{10}$CFU/g after 12 days of cold storage only in G3, while all the treated groups recorded <1 $\log_{10}$CFU/g in the 15th day with reduction percent to 100%.

Referring to TVN, the treatment with LP and OP improved the chemical quality and extended shelf-life of the treated groups significantly in comparison with a control group which showed spoilage signs on the 9th day of chilling storage. After 15 days of incubation, and although the treated samples were about to be deteriorated, TVN mean values still within the acceptable limits (≤20 mg/100g) in the treated groups (G2, G3 and G5), while it recorded ≥20 mg/100g in the G4 (Table, 7).

Regarding TBA values, Table (8) showed that the treatment with LP and OP improved the chemical quality and extended shelf-life of the treated groups significantly in comparison with a control group which showed spoilage signs on the 9th day of chilling storage. After 15 days of incubation, and although the treated samples were about to be deteriorated, TBA mean values still within the acceptable limits (≤0.9 mg malonaldehyde/Kg).

Table 1 Sensory profile of untreated and treated minced beef samples with citrus peels powders in cold storage (4±1OC).

Groups	Tested parameter	G1	G2	G3	G4	G5
Zero day	Color	4.6±0.16	4.6±0.16	4.6±0.16	4.6±0.16	4.6±0.16
	Odour	4.5±0.3	4.5±0.3	4.5±0.3	4.5±0.3	4.5±0.3
	Texture	4.7±0.4	4.7±0.4	4.5±0.4	4.6±0.4	4.5±0.4
	Overall	4.6±0.3^{a}	4.6±0.3^{a}	4.5±0.2 ^{a}	4.6±0.4^{a}	4.5±0.3 ^{a}
3nd day	Color	3.1±0.23	4.3±0.14	4.0±0.1	4.1±0.1	3.8±0.1
	Odour	3.7±0.16	4.3±0.12	3.8±0.2	4.2±0.3	3.5±0.3
	Texture	3.8±0.2	4.5±0.3	4.1±0.3	4.4±0.4	4.0±0.2
	Overall	3.5±0.1^{c}	4.4±0.2^{a}	3.9±0.3^{b}	4.2±0.2^{a}	3.8±0.3^{b}
6th day	Color	1.7±0.12	4.2±0.11	3.8±0.1	3.6±0.1	3.4±0.2
	Odour	2.2±0.23	3.8±0.16	3.7±0.2	3.8±0.28	3.2±0.28
	Texture	2.3±0.18	4.3±0.3	4.0±0.3	4.1±0.2	3.8±0.3
	Overall	2.1±0.2	4.1±0.3^{a}	3.8±0.2	3.8±0.3	3.5±0.1
9th day	Color	0.6±0.01	3.8±0.20	3.2±0.1	3.3±0.2	3.1±0.3
	Odour	1.0±0.2	3.8±0.2	3.3±0.3	3.5±0.3	3.0±0.2
	Texture	0.8±0.05	4.0±0.3	3.5±0.3	3.7±0.2	3.1±0.16
	Overall	0.8±0.01^{d}	3.9±0.2^{a}	3.3±0.2^{bc}	3.5±0.2^{b}	3.1±0.1^{c}
12th day	Color	<1	3.6±0.21	2.8±0.1	3.0±0.21	2.5±0.2
	Odour	<1	3.2±0.2	2.8±0.2	3.1±0.3	2.5±0.1
	Texture	<1	3.5±0.2	2.5±0.1	2.8±0.1	2.4±0.1
	Overall	<1	3.4±0.3^{a}	2.7±0.1^{c}	3.0±0.2^{b}	2.5±0.1^{d}
15th day	Color	<1	3.3±0.27	2.0±0.15	2.5±0.3	2.3±0.1
	Odour	<1	2.8±0.3	2.6±0.16	2.7±0.2	2.3±0.2
	Texture	<1	3.0±0.2	2.0±0.08	2.1±0.1	1.4±0.1
	Overall	<1	3.0±0.2^{a}	2.2±0.1^{c}	2.4±0.1^{b}	2.0±0.1^{d}

The values represent Mean ± SE of three experiments.
Means within the same row (abcd) followed by different superscript letters are highly significantly different (P ≤ 0.05).
Zero time: 30min after inoculation.
4.0-5.0 very good 3.1-3.9 good 2.1-3.0 Acceptable 1.1-2.0 Unacceptable 0.0-1.0 spoiled
G1: Control untreated minced beef
G2: Treated minced beef with lemon peel powder(%٥)
G3: Treated minced beef with lemon peel powder(%١٠)
G4: Treated minced beef with orange peel powder(%٥)
G5: Treated minced beef with orange peel powder (10%)

Table 2 Average values and reduction % of APC (log10 CFU/g) in minced beef groups at chilled storage (4±1OC).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%
Zero day	5.70±0.4^{a}	5.70±0.4^{a}		5.70±0.4^{a}		5.70±0.4^{a}		5.70±0.4^{a}	
3rd day	5.63±0.3^{a}	5.51±0.5^{b}	3.33	4.20±0.2^{d}	26.32	5.35±0.5^{b}	6.14	4.46±0.3^{ab}	21.75
6th day	6.61±0.6^{a}	4.41±0.6^{c}	22.6	4.11±0.2^{d}	27.89	4.49±0.4^{b}	21.23	4.38±0.4^{c}	23.16
9th day	7.11±0.6^{a}	4.30±0.3^{c}	24.56	3.98±0.4^{d}	31.75	4.44±0.3^{b}	22.11	4.27±0.4^{c}	25.10
12th day	S.	4.00±0.4^{b}	29.82	3.81±0.3^{c}	33.16	4.36±0.3^{a}	23.51	4.17±0.5^{b}	26.84
15th day	S.	3.80±0.3^{b}	33.33	3.69±0.2^{c}	35.26	4.27±0.2^{a}	25.10	4.04±0.6^{b}	29.12

Table 3 Average values and reduction % of Enterobacteriaceae count (EC) (log10 CFU/g) in minced beef groups at chilled storage (4±1OC).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%
Zero day	2.97±0.1^{a}	2.97±0.1^{a}	--	2.97±0.1^{a}	--	2.97±0.1^{a}	--	2.97±0.1^{a}	--
3nd day	3.47±0.2^{a}	2.69±0.3^{c}	9.43	2.32±0.1^{e}	21.88	2.78±0.1^{b}	6.39	2.50±0.1^{d}	15.82
6th day	3.95±0.3^{a}	2.27±0.2^{c}	23.56	1.5±0.04^{d}	49.49	2.55±0.3^{b}	14.14	2.15±0.2^{c}	27.60
9th day	4.61±0.3^{a}	1.20±0.2^{c}	59.89	<1	100	1.99±0.2^{b}	32.99	1.56±0.2^{d}	47.47
12th day	S.	0.92±0.01	69.02	<1	100	1.25±0.1	52.29	<1	100
15th day	S.	<1	100	<1	100	<1	100	<1	100

Table 4 Average values and reduction % of E. coli count (log10 CFU/g) in minced beef groups at chilled storage (4±1OC).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%
Zero day	2.97±0.1[a]	2.97±0.1[a]	--	2.97±0.1[a]	--	2.97±0.1[a]	--	2.97±0.1[a]	--
3nd day	3.47±0.2[a]	2.69±0.3[c]	9.43	2.32±0.1[e]	21.88	2.78±0.1[b]	6.39	2.50±0.1[d]	15.82
6th day	3.95±0.3[a]	2.27±0.2[c]	23.56	1.5±0.04[d]	49.49	2.55±0.3[b]	14.14	2.15±0.2[c]	27.60
9th day	4.61±0.3[a]	1.20±0.2[c]	59.89	<1	100	1.99±0.2[b]	32.99	1.56±0.2[d]	47.47
12th day	S.	0.92±0.01	69.02	<1	100	1.25±0.1	52.29	<1	100
15th day	S.	<1	100	<1	100	<1	100	<1	100

Table 5 Average values and reduction % of Staphylococcus aureus count (log10 CFU/g) in minced beef groups at chilled storage (4±1OC).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%
Zero day	2.54±0.2	2.54±0.2	--	2.54±0.2	--	2.54±0.2	--	2.54±0.2	--
3nd day	2.85±0.2	2.04±0.2	19.68	2.00±0.3	21.18	2.23±0.2	12.20	2.15±0.2	15.35
6th day	3.04±0.2	1.85±0.05	27.16	1.63±0.1	35.82	1.93±0.2	24.02	1.86±0.2	26.77
9th day	3.17±0.3	1.47±0.1	42.12	<1	100	1.69±0.1	33.46	<1	100
12th day	S.	<1	100	<1	100	<1	100	<1	100
15th day	S.	<1	100	<1	100	<1	100	<1	100

Table 6 Average values and reduction % of yeast and mold count (log10 CFU/g) in minced beef groups at chilled storage (4±1OC).

Groups	G1	G2	R%	G3	R%	G4	R%	G5	R%
Zero day	2.78±0.1	2.78±0.1	--	2.78±0.1	--	2.78±0.1	--	2.78±0.1	--
3nd day	2.98±0.1	2.39±0.1	14.02	2.20±0.2	20.86	2.53±0.1	8.99	2.53±0.3	8.99
6th day	3.15±0.3	2.04±0.1	26.62	1.96±0.2	29.49	2.34±0.2	15.82	2.32±0.2	16.54
9th day	3.41±0.3	1.88±0.1	32.37	1.0±0.1	64.03	1.98±0.2	28.77	2.00±0.1	28.10
12th day	S.	1.20±0.01	56.83	<1	100	1.66±0.1	40.28	1.41±0.1	49.64
15th day	S.	<1	100	<1	100	<1	100	<1	100

Table 7 Average values of TVN (mg/100g) in the minced beef groups during chilled storage (4±1°C).

Groups	G1	G2	G3	G4	G5
Zero day	10.6±0.10[a]	10.43±0.06[a]	10.1±0.06[a]	10.6±0.1[a]	10.3±0.12[a]
3nd day	13.1±0.21[a]	10.8±0.11[c]	10.5±0.2[c]	11.4±0.05[b]	10.5±0.23[c]
6th day	16.5±0.17[a]	12.7±0.14[c]	11.7±0.2[d]	13.2±0.26[b]	12.0±0.14[d]
9th day	20.6±0.25[a]	15.5±0.2[c]	14.4±0.11[d]	16.0±0.08[b]	14.8±0.15[d]
12th day	S.	17.3±0.11[b]	16.2±0.14[d]	17.7±0.21[a]	16.7±0.17[c]
15th day	S.	19.6±0.24[b]	18.3±0.21[d]	20.0±0.11[a]	18.5±0.23[c]

Table 8 Average values of TBA (mg malonaldehyde/Kg) in the minced beef groups during chilled storage (4±1°C).

Groups	G1	G2	G3	G4	G5
Zero day	0.41±0.01[a]	0.39±0.01[a]	[G]0.37±0.01[a]	[F]0.41±0.01[a]	[E]0.38±0.01[a]
3nd day	0.58±0.01[a]	0.42±0.01[c]	0.40±0.01[c]	0.46±0.01[b]	0.42±0.01[c]
6th day	0.74±0.01[a]	0.54±0.04[b]	0.47±0.03[d]	0.58±0.01[b]	0.50±0.02[c]
9th day	0.95±0.02[a]	0.61±0.01[b]	0.54±0.01[c]	0.66±0.01[b]	0.57±0.01[c]
12th day	S.	0.72±0.01[a]	0.63±0.01[b]	0.78±0.01[a]	0.66±0.01[b]
15th day	S.	0.81±0.01[a]	0.75±0.02[b]	0.85±0.02[a]	0.78±0.01[b]

4. DISCUSSION

Application of chemical synthetic food-additives to control the undesirable degradation of fatty-proteinaceous foods has been restricted because of their side effects as hepato-nephro-toxicity and mutagenic effect. So, its restoration with natural additives of antioxidant properties demand increased to meet the consumer's need to healthy food products (Lourenço *et al.*, 2019).

The obtained results of sensory analysis agree, quite well, with those recorded by Ibrahim *et al.* (2018) who recorded significant improvement of the sensory scores of the treated minced meat with lemon and orange peel powders during refrigeration storage for 15 days, which was superior in lemon peel powder-treated samples over that in orange peel powder-treated samples, which were more significant with higher concentrations.

In addition, Chappalwar *et al.* (2021) recorded physical character improvement in the treated chicken panée with lemon peel powder, while increasing the lemon peel concentration revealed a significant drawback in the sensory grades due to yellowness and pungent flavor. Likewise, the

results reported by Abdel-Naeem *et al.* (2022) who examined lemon and orange treated frozen chicken meat along 3 months, revealed an improvement in sensory characters for the lemon peel powder-treated samples. These results came in contrast with findings of Mahmoud *et al.* (2017) who recorded a significant decrease of the sensory scores of the treated beef burger with orange peel powder (2.5%, 5%, 7.5%, and 10%), among all treatments the best scores were recorded in 5% orange peel powder-treated samples.

The improvement in the flavor of the treated samples with citrus fruits may be attributed to the presence of aromatic compounds, which have been produced as metabolites during its ripening or due to their high flavonoid compounds (Gowe, 2015).

The phenolic compounds of the citrus peel powder exhibit antimicrobial effect through decreasing the internal pH value of microbial cells through the ionization of acid molecules; also, by altering cell membrane permeability causing disruption of substrate transport (Haque *et al.*, 2020). Also, addition of citrus fruit powder to meat products decreases the water content and alters the bacterial growth (Abdel-Naeem *et al.*, 2022).

The attained results revealed a significant reduction of microbiological counts in all treated samples as was typed in Tables (2 to 6). Higher powder concentration (10%) showed more antimicrobial effects, but due to their pungent citrus flavor made it unfavorable, while both of the peel powders at (5%) had an antimicrobial effect with the balanced favorable physical character of the treated samples. Comparing with orange peel powder at the same concentration (5%), lemon peel powder seems to be more effective in inhibition of the microbial growth, which may be attributed to its higher total polyphenol content (Abdel-Naeem *et al.*, 2022).

The obtained results came in agree with those recorded by Narkhede (2012) who documented significant lower total mold-yeast count in the treated beef and chicken nuggets with lemon peel powder; Abd El-Khalek and Zahran (2013) who recorded a considerable reduction in the APC in ground meat samples treated with orange powders with an extension of their shelf life to 21 days of cold storage; Alahakoon *et al.* (2013) who found significant microbial inhibition in the citrus peel treated chicken breast meat sample during different storage temperatures Also, addition of orange or lemon peel powders (1 or 2%) to beef induced a significant decrease in the APC during refrigeration for 15 days which may be attributed to that the peel powders caused sudden lethal effects for microorganisms as was recorded by Ibrahim *et al.* (2018).

Chemical indices (TVN and TBA) indicating the level of protein deterioration and lipid oxidation and the recommended permissible limits by ES (1694/2005) were recorded in Tables (7 and 8). The current results came in agreement with the obtained results by Ibrahim and Salem (2013) who detected significant declined TBA values for the products treated with lemon peel; Borah *et al.* (2014) who declared that citrus peel extracts were effective in maintaining low TBA values in chicken meatballs for 15 days of cold storage; Klangpetch *et al.* (2016) who recorded decrease in the lipid oxidation for more than 40% in samples treated with lemon peel; Ibrahim *et al.* (2018) who recorded retardation in the TVN values in the lemon peel powder (2%) treated samples up to 15 days of cold storage. Furthermore, Abdel-Naeem *et al.* (2022) reported slower TVN elevation after treatment with fruit peel powders due to its inhibitory effect due to their bioactive compounds against microbial growth and internal enzyme activities.

These natural additives prohibit microbial lipid deterioration by reducing microbial growth and strong antioxidant activity (Narkhede, 2012). Additionally, Gorinstein *et al.* (2001) attributed that to the antioxidant potency of lemon peel powder which is thought to be higher than that of orange peel powder due to the highly total polyphenol content due to their redox properties, which can play a great role in adsorbing and neutralizing free radicals, quenching singlet oxygen or decomposing peroxides (Cao *et al.*, 1997).

Regarding the critical causes of meat spoilage, increased microbial counts and enzymatic activity enhanced the breakdown of lipid and proteins (Iulietto *et al.*, 2016); in the current study, although addition of citrus peel powders resulted in reduction in the microbial growth, TVN and TBA levels slowly increased in comparison with a control untreated group which may be attributed to many theories like the action of autolytic enzymes that initiate endogenous autolytic processes in the muscle fiber of slaughtered animal where the complex compounds are broken-down into simpler ones including proteolysis and fat hydrolysis which are pH\temperature dependent process (Kuwahara and Osako, 2003) essential for microbial growth and decomposition resulting in softening and exudative changes of the meat called self-deterioration (Tauro *et al.*, 1986). In addition, Ghaly *et al.* (2010) concluded that cold stored meats can be spoiled by lytic enzymes either endogenous of food product or secreted from psychrotrophic microorganisms.

5. CONCLUSION

In conclusion, lemon and orange peel powders had general enhancement in extending shelf-life and quality attributes of minced beef during chilled storage. Consequently, lemon peel powder especially at 5% was the most effective and recommended.

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