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Effect of Adding Tomato Pomace, Potato Peel, and Lemon Peel Powders on Some Quality Properties of Beef Burger during Frozen Storage

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Abstract

Food processing residues may be biologically treated and turned into more valuable products, raw materials for other industries, or even food or feed. If the necessary technical methods existed and the value of the final products has been to exceed the cost of reprocessing, these conversions may be regarded as valuable. The objectives of this investigation were to provide a partial solution to some nutrition problems as overweight and obesity through the utilization of fruit and vegetable by-products as a good source of fiber ingredients and antioxidant bioactive components i.e., tomato pomace powder (TPP), potato peel powder (PPP), and lemon peels powder (LPP)]. The obtained results indicated that adding TPP, PPP and LPP at different levels prevented the growth of microorganisms and retarded the development of rancidity in beef burgers as compared to the control samples, even after 3 months of frozen storage at -18°C. Beef burger with TPP, PPP at 4 and 8 %) and LPP at 1 and 2 %, demonstrated the highest protection against reducing the values of TVBN and TBA during frozen storage periods. Also, beef burger containing TPP, PPP and LPP exhibited the desired good quality parameters and better acceptability, and also improve the nutritional value materials cheap ingredients and can reduce production costs. These by-products should be further utilized rather than just discarded as waste.

Keywords: Tomato pomace, Potato peel, Lemon peel, Beef burger, TVBN, TBA, quality.

Introduction

As a result of the food insecurity associated with malnutrition and the possibility of infectious diseases. The consumer has taken great interest in diets' health and nutritional components and has identified good strategies to tackle malnutrition and alleviate its various associated health disorders. (**Akhtar *et al.*, 2013**; and **Sagar *et al*, 2018**).

About 1.3 billion tons of the food produced around the world wide is lost during the food chain. Food security is a major concern in developing countries, food production must increase significantly to meet future demand in a way that assures a balance between the available and limited natural resources (**FAO, 2014**; and **Trigo *et al*., 2020**).

Meat is the most valuable livestock product and for many people serves as their first-choice source of animal protein. The meat is either consumed as a component of kitchen-style food preparations or as processed meat products. Processed meat products are globally gaining ground in popularity and consumption volume (**Almeida *et al*., 2019**).

Beef burger patties are a beef derivative that has high acceptability in the market, and its products can be presented as an option for increasing the profits of meat processing companies (**de-Araújo *et al*., 2020**; and **Ramos *et al*., 2021**).

Tomato by-products are rich in multiple components with antioxidant and colorant properties such as carotenoids (lycopene, β-carotene, phytoene, phytofluene and lutein), phenolic compounds (phenolic acids and flavonoids), vitamins (ascorbic acid and vitamin A) and glycoalkaloids (tomatine) (**Domínguez *et al*., 2020**).

Tomato powder in beef burgers resulted in low color scores than the control, probably due to an increase in the red/orange tone of these samples producing a color very different from that expected in a conventional burger (**Domínguez *et al*., 2020**).

Potato is one of the major foods of the human diet that grows in more than 100 countries. It's the fourth largest crop grown worldwide, with a world annual production of 367.75 million tons (**FAO, 2014**). The potato peels provide an excellent source of extractable TPC since almost 50% of phenolic compounds are located in the peel and decrease toward the center of the potato tuber (**Ahmed Al-Masri, 2012**).

Citrus limon waste is considered a valuable economic and renewable source for cosmetics pharmaceuticals, health industries, and functional foods. Moreover, these reuse strategies could allow food industries to reduce the amount of waste and the costs of its disposal as organic matter, obtaining new commercial products (**Panwar *et al*., 2021**).

Keeping in view that the development of value-added products from diverse raw ingredients is receiving the prime focus of food processing industries and researchers, the present study was planned to utilization of some food wastes such as tomato pomace powder (TPP), potato peel powder (PPP), and lemon peel powder (LPP) as a good source of patty samples. Total volatile basic nitrogen (TVBN) valuation of the effect of adding these by-products with the different evels on beef burger qualities and characteristics.

Materials and Methods

Materials:

Beef and by-products:

Fresh beef lean (from the round) and beef back fat from the same beef carcasses were purchased from a slaughterhouse at an Egyptian local market (Giza, Egypt). Tomato pomace (peel and seeds) was obtained from Heinz Company (Cairo Food Industrial Heinz Egypt) for Foodstuffs, 6th of October City (2), Giza, Egypt. Potato peel was obtained from Egypt Foods Co., industrial zoon, Quesna city, Egypt. Fresh Lemon fruit was purchased from an Egyptian local market in Giza, Egypt. The soy granules were obtained from Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. Spices, salt, eggs, bread crumbs, fresh onion, and water were obtained from the local market in Giza, Egypt.

Chemicals:

All chemicals used in this study for analysis were of analytical grade. hydrochloric acid (HCl), sulfuric acid (H_2SO_4), sodium hydroxide (NaOH), boric acid (H_3BO_3), tartaric acid ($C_4H_6O_6$), copper sulphate ($CuSO_4$), potassium sulphate (K_2SO_4), ethanol alcohol 95%, azelaic acid ($C_9H_{16}O_4$), bromothymol blue ($C_{21}H_{13}Br_4NaO_5S$), glacial acetic acid ($C_2H_4O_2$), thiobarbituric acid (TBA) ($C_4H_4N_2O_2S$), methyl red ($C_{15}H_{15}N_3O_2$), magnesium oxide (MgO) and whatman filter paper (1, and 41), were purchased from Sigma Chemical Co..

Methods:

Preparation of Food processing residues:

The tested plant residue extracts were prepared according to **Zia-ur-Rehman (2006).** The obtained residues in fresh status were transferred immediately to the analytical lab. After removing the unsymmetrical parties, each residue was divided into two portions and then dried by both electric and solar dryers. The oven-dried residues were dried at 40-50°C gradually for 12 h. Where the solar-dried residues were dried at ~38-40°C for 72 h till the weight was stable. Then it was milled to a fine powder using a mechanical laboratory grinder, kept in polyethylene bags and stored at (-18±1°C) until used.

Preparation of beef burger:

Beef burger treatments were prepared according to the formula reported by (**Baioumy, and Abedelmaksoud (2021)**). The processing of the beef burger was carried out according to the **Egyptian Standard** of frozen beef burgers **(ES: 1688/2005 ICS: 67.120.10)**. Tomato pomace, potato peel, and lemon peel were added at different levels to the ground meat and other formulas components, mixed until a homogeneous distribution, and shaped into patty 10 cm diameter, 1.5 cm thickness. All beef burger samples were aerobically packaged in foam plates, wrapped with polyethylene film and stored at (-18±1˚C) for 3 months. The samples were taken for analysis every month periodically. The beef burger containing different plant residue extracts was cooked in a preheated electrical grill for 4 minutes (2 min. on each side) at 110°C before being coded and evaluated and determination of cooking measurements (cooking yield and shrinkage).

Added rates of plant residue to beef burgers:

1) Tomato pomace powder (4, 8 and 12%),
2) Potato peels powder (4, 8 and 12%), and
3) Lemon peel powder (1, 2 and 3%).

Analytical methods:

1. Gross chemical composition:

Moisture, crude protein, ash, and ether-extract contents were determined according to the methods of **AOAC. (2010)**. Total carbohydrate content was calculated by difference as follows: **Total Carbohydrate = 100 - % (Ash + Protein + Fat + Moisture) (Merrill and Kunerth, 1973)**

Total volatile bases nitrogen (TVBN):

The total volatile nitrogen of beef burger products was determined by the method described by **Winton and Winton (1958)**.

Thiobarbituric acid test (TBA):

TBA test is a sensitive test for the decomposition product of highly unsaturated fatty acids, which do not appear in peroxide number determination (**Du and Ahn, 2002; and AOCS., 2006**).

The TBA as an indication for lipid oxidation was determined according to the method described by **Kirk and Sawyer (1991)**.

2. Physicochemical analysis:

pH value:

The pH was measured using a pH meter at 20ºC according to the method described by **Fernández-López *et al.* 2006**.

Water holding capacity, and Plasticity:

Water holding capacity (WHC) and plasticity of beef burger samples products were measured by filter press method according to (**Chau and Huang, (2003)**.

3. Cooking properties:

The beef burger samples were cooked using an electrical grill at 110 °C for 4 minutes (2 min. on each side) and determined cooking loss and shrinkage.

Cooking loos:

The cooking loss of prepared beef burger samples was calculated according to the method described in **AMSA. (1995)**.

Shrinkage value:

The shrinkage value (Diameter reduction) (%) of prepared beef burger samples was calculated as the decrease in diameter and thickness of the sample according to the method described in **AMSA. (1995)**.

Statistical analysis:

The statistical analysis were carried out using two-way ANOVA using SPSS, ver. 27 **(IBM Corp. Released 2013)**. The obtained data were treated as a complete randomization design according to **Steel *et al.* (1997)**. Multiple comparisons carried out applying **Duncun test.** Significance level was set at < 0.05.

Results and Discussion

Chemical composition of produced Beef burger:

Data in **Table (1)** showed that the moisture content of all samples was slightly decreased during frozen storage periods. The control samples for beef burgers had moisture content ranged from 68.49 to 67.29 % at zero time, and 3 months of frozen storage compared with TPP (67.85 to 62.74 %), samples containing PPP (67.63 to 62.54 %), and samples containing LPP (68.19 to 66.34 %) at zero time, and 3 months. This decrease in moisture content during storage may be due to the drip loss and partially the evaporation through the polyethylene bags, which were used for beef burger packing and the decrease of protein solubility and subsequently the reduction of water holding capacity (WHC), as reported by **Makris *et al.* (2007)**; **Al-Weshahy and Venket (2009); Abd Elaal and Halaweish (2010)**; **Ahmed Al-Masri (2012); El-badrawy and Sello (2016); Ibrahim *et al.* (2018)**; and **Thieme *et al.* (2019)**.

Data in **Table (2)** showed that the crude protein of all samples was slightly decreased during frozen storage periods. The control samples for beef burgers had crude protein ranged from 19.54 to 18.92 % at zero time, and 3 months of frozen storage compared with LPP (19.28 to 17.19 %), samples containing TPP (18.14 to 15.14 %), and samples containing PPP (18.11 to 14.95 %) at zero time, and 3 months. The decrease in the crude protein of these samples during frozen storage might be due to a slight loss of nitrogen (as volatile nitrogen) as a result of slight protein breakdown by some microorganisms as reported by **Makris *et al.* (2007)**; **Al-Weshahy and Venket (2009); Abd Elaal and Halaweish (2010)**; **Ahmed Al-Masri (2012); El-badrawy and Sello (2016); Ibrahim *et al.* (2018)**; and **Thieme *et al.* (2019)**.

Data in **Table (3) indicated that** the ash content of all samples was slightly increased during frozen storage periods. The control samples for beef burgers had ash content ranged from 2.53 to 2.86 % at zero time, and 3 months of frozen storage compared with TPP (2.85 to 3.11 %), samples containing PPP (2.81 to 3.02 %) and samples containing LPP (2.61 to 2.92 %) at zero time, and 3 months. The increase in ash content of these samples might be due to the losses of moisture and protein contents during frozen storage by some microorganisms, as reported by **Makris *et al.* (2007)**; **Al-Weshahy and Venket (2009); Abd Elaal and Halaweish (2010)**; **Ahmed Al-Masri (2012); El-**

badrawy and Sello (2016); Ibrahim *et al.*, (2018); and **Thieme *et al.*, (2019)**.

Data in **Table (4)** showed that the effect of mixing in different levels of TPP, PPP and LPP on ether extract content of beef burger during frozen storage at -18±1°C for 3 months.

Data in **Table (5)** observed that the total carbohydrates content of all samples was slightly increased during frozen storage periods. The control samples for beef burgers had total carbohydrates content ranged from 4.65 to 5.87 % at zero time, and 3 months of frozen storage compared with PPP (6.96 to 15.10 %), samples containing TPP (6.60 to 14.74 %), and samples containing LPP (5.34 to 8.88 %) at zero time, and 3 months. These results are in agreement with those obtained by **Makris *et al.* (2007)**; **Al-Weshahy and Venket (2009); Abd Elaal and Halaweish (2010)**; **Ahmed Al-Masri (2012); El-Badrawy and Sello (2016); Ibrahim *et al.*, (2018)**; and **Thieme *et al.*, (2019)**. According to **The Egyptian Standard for frozen beef burgers (ES: 1688/2005 ICS: 67.120.10)**, the levels moisture, crude protein, fat and carbohydrate contents should be 60, 15, 20 and 10%, respectively.

Total volatile bases nitrogen of produced beef burger:

During frozen storage at -18±1°C for 3 months, the total volatile bases nitrogen (TVBN) of beef burger samples was affected by type and levels of TPP, PPP and LPP. Meat quality is primarily determined by the TVBN content of the meats. As a result, it is a significant predictor of the freshness of the meat in this situation because the TVBN content is influenced by the amount of ammonia and amines produced by protein degradation through enzymatic and microbiological processes (**Omana *et al.*, 2011**).

Data in **Table (6)** cleared that the initial TVBN content in control sample was 8.53 mg /100 g. While, the samples contain TPP, PPP, and LPP with different levels (7.71, 7.70, 7.42), (8.03, 7.76, 7.74) and (7.40, 7.08, 7.03) mg/100 g, respectively. Moreover, the saple content TPP, PPP, and LPP were decrease the rate of TVBN formation during frozen storage as compared with control sample. It has been illustrated that the increase in TVBN is caused by the microbiological deamination of amino acids as well as the complete microbial reduction of trimethylamine-N-oxide (TMAO) to trimethylamine (TMA) (**Tomac *et al.*, 2014; and Saleh *et al.*, 2022)**). However, **The Egyptian Standard for meat products (ES: 1972/2005a)** stated that TVBN should not exceed 20 mg/100g. These results are in agreement with those obtained by **Saleh *et al.*, (2022).**

Thiobarbituric acid of produced Beef burger:

Data in **Table (7)** showed the effect of TPP, PPP, and LPP on TBA value on a beef burger. There was a gradual increase in TBA values for all examined samples during the storage period.

Non significant differences were observed between treated beef burgers and control sample at zero time. TBA value was 0.211 mg/kg, for the control sample, while it was 0.214, 0.209, and 0.201 mg MD/Kg for beef burger sample with 4, 8, and 12% of TPP, respectively and 0.207, 0.208, and 0.208 mg/kg for beef burger sample enriched with 4, 8, and 12% of PPP, respectively, and 0.208 mg/kg for beef burger with 4, 8, and 12% of LPP, respectively.

In general, the storage time had a significant influence on the processing development of lipid oxidation in all investigated samples. However, the development rates of TBA values in TPP, PPP, and LPP-treated beef burgers were very slow. **The Egyptian Standard for meat products (ES: 1972/2005b)** stated that TBA values should not exceed 0.9 mg MD/Kg. The results showed that adding TPP, PPP, and LPP protected beef burgers against lipid oxidation. Phenolic compounds have been known to inhibit free radical formation and the propagation of free radical reactions through the chelation of transition metal ions, such as iron (**McBride *et al.*, 2007**). These results are in near agreement with those reported by **Omana *et al.* (2011)**.

Physicochemical properties:

1. pH Values:

Data in **Table (8)** showed that the control sample of the beef burger had an initial pH value of 5.78 at zero time which significantly increased during the 1st, 2nd and 3rd month of storage to 5.99, 6.09, and 6.15, respectively.

For beef burger samples formulated by substituted 12% of TPP were increased from 4.47 at zero time to 4.53, 5.06, and 5.18, while, in beef burger samples formulated by substituted 12% of PPP increased from 5.83 to 5.85, 6.11, and 6.16, and while, in beef burger samples formulated by substituted 3% of LPP increased from 4.72 at zero time to 4.88, 5.25, and 5.37, during frozen storage periode, respectively.

These results are in near agreement with those reported by **Zhang *et al.* (2012)**. Generally, it was shown the pH value increased gradually with increasing storage time (**Table (6)**).

Ibrahim *et al.* (2018) and **Thieme *et al.* (2019)** also reported that an increase in pH during the storage period may be due to the growth of Gram-negative bacteria and due to the accumulation of metabolites by bacterial action on protein and amino acids.

The formation of acidic compounds may be attributed to the activity of lactic acid bacteria. Generally, these results are in agreement with those obtained by **Saleh *et al.*, (2022).**

2. Water holding capacity, and plasticity changes:

The water-holding capacity (WHC) of meat is defined as the ability of meat to hold its own or add water during processing. It is considered an important factor affecting eating quality, tenderness, juiciness, thawing drip and cooking loss of meat.

Data in **Table (9)** showed the effect of TPP, PPP and LPP on WHC of produced beef burger. WHC was 3.27 cm^2/0.3g in the control sample at zero time. While, during frozen storage, the WHC value showed a gradual increment for all treated samples. The highest value has recorded for beef burger sample with 12% PPP in 3 months of storage (3.88 cm^2/0.3g).

On the other hand, the lowest WHC value was found in control samples at zero time. WHC values beef burger with PPP samples were higher than beef burger with TPP and LPP samples which may be due to the high content of fiber in PPP (44.67%) compared to those of LPP (11.40%). These results are in near agreement with those reported by **Alvarez and Barbut (2013)**.

Plasticity of meat samples indicates the tenderness of the meat. Palatability is also affected by pH and water holding capacity. During frozen storage at -18±1°C for 3 months, the changes in the plasticity of beef burger samples. **Table (10)** showed the effect of TPP, PPP, and LPP on plasticity (cm^2/0.3 g). Plasticity was 3.03 cm^2/0.3 g in the control sample at zero time. During storage, the plasticity value was a gradual decrement for all treated samples. The lowest plasticity value was recorded for beef burger with 12% PPP and 3% LPP samples in 3 months of storage (2.20 cm^2/0.3 g). On the other hand, the highest plasticity value was found in control sample at zero time. TPP beef burger samples showed higher plasticity values than beef burger with PPP and LPP samples which may be due to the antioxidant and antimicrobial activity of TPP, PPP and LPP. These results are in near agreement with those reported by **Verbeken *et al.*, (2005)**; and **Alvarez and Barbut (2013)**.

Cooking properties of beef burgers:

1. Cooking loos of beef burgers:

During frozen storage at -18±1°C for 3 months, the cooking loss of beef burgers as affected by type and levels of TPP, PPP and LPP, is presented in **Table (11)**. Cooking loss of beef burger samples containing TPP and PPP at levels of 8, and 12%, and LPP at levels of 2, and 3% was lower (15.75 and 15.43%), (15.65 and 15.64%), and (15.69 and 15.54%), respectively, but the cooking loss of the control sample was slightly high (16.92%) at zero time.

The highest cooking losses were recorded for control samples (21.84%). Meanwhile, the lowest values were recorded for samples containing 12% TPP after 3 months of storage.

This is due to the protein denaturation and loss of protein solubility which led to a decrease in the water-holding capacity (**Abd El-Qader, 2014**). These results are in agreement with those found by **Aleson-Carbonell *et al.*, (2005); Hassan (2010); Al-Hakeem (2012); and Ibrahim *et al.*, (2018)**.

2. Shrinkage of beef burgers:

During frozen storage at -18±1°C for 3 months, the effect of TPP, PPP, and LPP on the shrinkage (%) of beef burger samples, as illustrated in **Table (12)**. The substituted of TPP, and PPP at levels of (4 - 12%) and LPP at levels of (1-3%) resulted in a gradual ($P < 0.05$) decrease in the shrinkage percent (from 13.25 to 12.13%, at zero time) of beef burger samples when compared with those of control sample (13.72%). Also, it could be observed that the shrinkage % of beef burger samples decreased ($P < 0.05$) by increasing TPP, and PPP levels from 4 to 12%) and LPP from 1 to 3%). PPP was the most effective in reducing the shrinkage% from 13.25 to 12.43% for beef burger samples followed by LPP and TPP.

The shrinkage linearly increased with increasing frozen storage time in all beef burger samples, but it was more evident in the control sample than in other samples containing TPP, PPP and LPP. This might be due to loss of protein solubility which led to a decrease in water holding capacity **(Abd El-Qader, 2004)**. Generally, the shrinkage% reached to range from 17.37 to 18.15% for beef burger samples containing PPP, LPP, and TPP, after 3 months of frozen storage as compared with the control sample which recorded 18.64%.

These results are in agreement with following those found by **EL-Kordy (2006)** and **Mohamed (2011)**, who found that the shrinkage % of beef burgers was increased by increasing the frozen storage period. These results are in near agreement with those reported by **Alvarez and Barbut (2013)**.

Conclusion

Food processing residues may be biologically treated and turned into more valuable products, raw materials for other industries, or even food or feed. If the necessary technical methods existed and the value of the final products has been to exceed the cost of reprocessing, these conversions may be regarded as valuable.

Finally, the results indicated that substituted TPP, PPP and LPP at different levels prevented the growth of microorganisms and retarded the development of rancidity in beef burgers as compared to the control samples, even after 3 months of frozen storage. Additionally, it was shown that the TPP, PPP (with concentrations 4 and 8 %) and LPP (with concentrations 1 and 2 %), demonstrated the highest protection against reducing the values of TVBN, and TBA in beef burgers during frozen storage period. Beef burgers containing TPP, PPP and LPP exhibited the desired good quality parameters and better acceptability, materials cheap ingredients and can reduce production costs and also improve the nutritional value and health value of beef burgers. These by-products should be further utilized rather than just discarded as waste.

Table 1. Effect of frozen storage period at -18°C on moisture content of produce beef burger substituted by TPP, PPP and LPP at different levels (g/100g on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	1st month	2nd month	3rd month		
Control sample		**68.49±0.601**	**68.14±0.211**	**67.51±0.224**	**67.29±0.127**	**67.86**	**0.194**
TPP	**4 %**	67.85±0.098	67.65±0.137	67.20±0.215	66.61±0.092	67.33	
	8 %	65.61±0.478	65.52±0.104	65.38±0.171	64.71±0.144	65.31	
	12 %	63.77±0.079	63.57±0.215	63.31±0.246	62.74±0.136	63.35	
PPP	**4 %**	67.63±0.168	67.36±0.244	66.97±0.420	66.36±0.136	67.08	
	8 %	65.47±0.155	65.43±0.176	65.19±0.190	64.33±0.260	65.11	
	12 %	63.34±0.216	63.28±0.173	62.81±0.085	62.54±0.227	62.99	
LPP	**1 %**	68.19±0.127	68.10±0.208	67.41±0.231	66.97±0.261	67.67	
	2 %	67.97±0.199	67.88±0.132	67.37±0.195	66.75±0.221	67.49	
	3 %	67.62±0.150	67.54±0.148	67.23±0.165	66.34±0.131	67.18	
LSD. (Samples) 0.05				**0.307**			

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 2. Effect of frozen storage period at -18°C on crude protein content of produce beef burger substituted by TPP, PPP and LPP at different levels (g/100g on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	1st month	2nd month	3rd month		
Control sample		**19.54±0.127**	**19.21±0.191**	**19.09±0.225**	**18.92±0.150**	**19.19**	**0.184**
TPP	**4 %**	18.14±0.179	17.83±0.121	17.67±0.185	17.48±0.115	17.78	
	8 %	17.43±0.127	17.31±0.069	17.18±0.179	16.96±0.133	17.22	
	12 %	15.64±0.179	15.48±0.092	15.31±0.179	15.14±0.191	15.39	
PPP	**4 %**	18.11±0.266	17.97±0.058	17.79±0.121	17.62±0.121	17.87	
	8 %	17.29±0.162	17.13±0.335	17.00±0.375	16.87±0.121	17.07	
	12 %	15.42±0.144	15.29±0.202	15.12±0.196	14.95±0.139	15.20	
LPP	**1 %**	19.28±0.11	19.11±0.219	18.90±0.173	18.73±0.658	19.01	
	2 %	18.87±0.144	18.68±0.329	18.54±0.144	18.37±0.173	18.62	
	3 %	17.74±0.104	17.53±0.110	17.34±0.219	17.19±0.260	**17.45**	
LSD. (Samples) 0.05				**0.291**			

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 3. Effect of frozen storage period at -18°C on ash content of produce beef burger substituted by TPP, PPP and LPP at different levels (g/100g on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	1st month	2nd month	3rd month		
Control sample		**2.53±0.120**	**2.68±0.064**	**2.79±0.069**	**2.86±0.081**	**2.71**	**0.075**
TPP	**4 %**	2.85±0.087	2.87±0.040	2.87±0.046	2.92±0.092	2.88	
	8 %	2.96±0.064	3.02±0.092	3.04±0.075	3.05±0.081	3.02	
	12 %	3.03±0.069	3.06±0.075	3.07±0.069	3.11±0.069	3.07	
PPP	**4 %**	2.81±0.069	2.83±0.088	2.89±0.075	2.95±0.098	2.87	
	8 %	2.84±0.179	2.87±0.110	2.94±0.104	2.96±0.081	2.90	
	12 %	2.92±0.092	2.98±0.064	2.99±0.115	3.02±0.087	2.98	
LPP	**1 %**	2.61±.040	2.76±0.075	2.79±0.098	2.90±0.098	2.77	
	2 %	2.64±0.046	2.77±0.133	2.81±0.064	2.91±0.087	2.78	
	3 %	2.66±0.069	2.82±0.052	2.88±0.052	2.92±0.064	2.82	
LSD. (Samples) 0.05			**0.118**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 4. Effect of frozen storage period at -18°C on ether extract content of produce beef burger substituted by TPP, PPP and LPP at different levels (g/100g on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	1st month	2nd month	3rd month		
Control sample		**4.79±0.185**	**4.86±0.248**	**4.94±0.081**	**5.06±0.115**	**4.91**	**0.143**
TPP	**4 %**	4.56±0.087	4.66±0.110	4.73±0.115	4.86±0.156	4.70	
	8 %	4.37±0.479	4.49±0.087	4.56±0.144	4.63±0.202	4.51	
	12 %	4.15±0.196	4.27±0.179	4.38±0.156	4.27±0.185	4.27	
PPP	**4 %**	4.43±0.156	4.59±0.075	4.67±0.167	4.79±0.115	4.62	
	8 %	4.31±0.133	4.46±0.144	4.54±0.087	4.66±0.133	4.49	
	12 %	4.09±0.248	4.18±0.173	4.29±0.144	4.39±0.174	4.24	
LPP	**1 %**	4.58±0.144	4.71±0.110	4.82±0.104	4.92±0.115	4.76	
	2 %	4.39±0.069	4.51±0.081	4.63±0.139	4.79±0.150	4.58	
	3 %	4.29±0.219	4.36±0.133	4.59±0.075	4.67±0.104	4.48	
LSD. (Samples) 0.05			**0.226**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 5. Effect of frozen storage period at -18°C on total carbohydrate content of produce beef burger substituted by TPP, PPP and LPP at different levels (g/100g on wet weight basis)

Level of substitution		**Storage period at -18±1°C**				**mean**	**LSD. 0.05 (Storage time)**
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**4.65±0.639**	**5.11±0.208**	**5.67±0.302**	**5.87±0.139**	**5.33**	**0.321**
TPP	**4 %**	6.60±0.243	6.99±0.155	7.53±0.134	8.13±0.175	7.31	
	8 %	9.63±0.927	9.66±0.075	9.84±0.361	10.65±0.391	9.95	
	12 %	13.41±0.135	13.62±0.366	13.93±0.577	14.74±0.324	13.93	
PPP	**4 %**	6.96±0.405	7.24±0.192	7.61±0.464	8.29±0.138	7.53	
	8 %	10.12±0.192	10.15±0.451	10.38±0.559	11.19±0.150	10.46	
	12 %	14.23±0.176	14.27±0.271	14.79±0.155	15.10±0.342	14.60	
LPP	**1 %**	5.34±0.125	5.38±0.237	6.08±0.202	6.48±0.431	5.82	
	2 %	6.13±0.303	6.16±0.637	6.65±0.340	7.18±0.202	6.53	
	3 %	7.69±0.492	7.75±0.210	7.96±0.511	8.88±0.424	8.07	
LSD. (Samples) 0.05			**0.508**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 6. Effect of frozen storage period at -18°C on TVBN content of produce beef burger substituted by TPP, PPP and LPP at different levels (mg/100g on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**8.53±0.384**	**10.65±0.431**	**15.24±0.291**	**19.44±0.322**	**13.47**	**0.338**
TPP	**4 %**	7.71±0.372	9.74±0.446	13.56±0.220	18.05±0.337	12.27	
	8 %	7.70±0.351	9.05±0.378	13.53±0.344	17.22±0.210	11.88	
	12 %	7.42±0.566	8.71±0.414	13.32±0.362	16.66±0.598	11.53	
PPP	**4 %**	8.03±0.217	10.22±0.316	14.33±0.174	18.52±0.396	12.78	
	8 %	7.76±0.380	9.84±0.324	13.81±0.116	17.53±0.424	12.24	
	12 %	7.74±0.419	9.52±0.533	13.64±0.639	16.81±0.302	11.93	
LPP	**1 %**	7.40±0.400	10.11±0.182	13.82±0.092	18.24±0.364	12.39	
	2 %	7.08±0.246	9.52±0.684	13.73±0.136	17.82±0.654	12.04	
	3 %	7.03±0.182	9.33±0.431	13.54±0.266	17.61±0.408	11.88	
LSD. (Samples) 0.05			**0.534**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table7. Effect of frozen storage period at -18°C on TBA content of produce beef burger substituted by TPP, PPP and LPP at different levels (mg malondialdehyde/kg on wet weight basis)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**0.21±0.015**	**0.35±0.099**	**0.59±0.038**	**0.87±0.031**	**0.50**	**0.026**
TPP	**4 %**	0.18±0.042	0.28±0.025	0.52±0.025	0.73±0.031	0.43	
	8 %	0.17±0.020	0.26±0.040	0.48±0.025	0.70±0.044	0.40	
	12 %	0.16±0.020	0.23±0.025	0.46±0.031	0.69±0.012	0.50	
PPP	**4 %**	0.19±0.042	0.30±0.040	0.54±0.026	0.77±0.025	0.45	
	8 %	0.17±0.021	0.28±0.043	0.50±0.020	0.75±0.044	0.43	
	12 %	0.16±0.040	0.27±0.038	0.48±0.023	0.72±0.026	0.41	
LPP	**1 %**	0.19±0.025	0.29±0.065	0.54±0.061	0.75±0.049	0.44	
	2 %	0.17±0.021	0.26±0.065	0.51±0.020	0.72±0.015	0.42	
	3 %	0.15±0.026	0.25±0.065	0.49±0.025	0.71±0.021	0.40	
LSD. (Samples) 0.05			**0.041**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 8. Effect of frozen storage period at -18°C on pH value of produce beef burger substituted by TPP, PPP and LPP at different levels

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**5.78±0.046**	**5.99±0.081**	**6.09±0.036**	**6.15±0.026**	**6.00**	**0.031**
TPP	**4 %**	5.24±0.020	5.29±0.027	5.66±0.009	5.71±0.023	5.48	
	8 %	4.75±0.022	4.84±0.022	5.28±0.013	5.34±0.029	5.05	
	12 %	4.47±0.030	4.53±0.012	5.06±0.003	5.18±0.029	4.81	
PPP	**4 %**	5.73±0.075	5.85±0.078	6.19±0.021	6.28±0.020	6.01	
	8 %	5.83±0.041	5.84±0.012	6.13±0.012	6.18±0.012	6.00	
	12 %	5.83±0.020	5.85±0.034	6.11±0.012	6.16±0.012	5.99	
LPP	**1 %**	5.08±0.048	5.31±0.015	5.65±0.019	5.73±0.018	5.44	
	2 %	4.81±0.042	4.93±0.015	5.35±0.023	5.42±0.021	5.13	
	3 %	4.72±0.047	4.88±0.018	5.25±0.020	5.37±0.020	5.06	
LSD. (Samples) 0.05			**0.048**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 9. Effect of frozen storage period at -18°C on WHC value of produce beef burger substituted by TPP, PPP and LPP at different levels (cm^2/0.3 g)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**3.27±0.127**	**3.36±0.049**	**3.44±0.093**	**3.5±0.067**	**3.39**	**0.058**
TPP	**4 %**	3.45±0.05	3.53±0.082	3.6±0.093	3.65±0.042	3.56	
	8 %	3.57±0.047	3.64±0.067	3.72±0.084	3.77±0.053	3.68	
	12 %	3.65±0.045	3.72±0.06	3.79±0.075	3.84±0.038	3.75	
PPP	**4 %**	3.47±0.051	3.56±0.031	3.63±0.061	3.69±0.061	3.59	
	8 %	3.59±0.05	3.68±0.053	3.75±0.044	3.81±0.079	3.71	
	12 %	3.68±0.065	3.72±0.064	3.83±0.047	3.88±0.055	3.78	
LPP	**1 %**	3.41±0.049	3.5±0.055	3.58±0.055	3.64±0.044	3.53	
	2 %	3.54±0.116	3.62±0.058	3.71±0.049	3.76±0.076	3.66	
	3 %	3.61±0.091	3.68±0.061	3.76±0.067	3.81±0.076	3.72	
LSD. (Samples) 0.05			**0.092**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 10. Effect of frozen storage period at -18°C on plasticity value of produce beef burger substituted by TPP, PPP and LPP at different levels (cm^2/0.3g)

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**3.03±0.045**	**2.92±0.056**	**2.78±0.05**	**2.58±0.129**	**2.83**	**0.063**
TPP	**4 %**	2.99±0.092	2.92±0.067	2.75±0.062	2.54±0.04	2.80	
	8 %	2.92±0.06	2.84±0.059	2.67±0.075	2.47±0.044	2.73	
	12 %	2.8±0.071	2.73±0.071	2.55±0.068	2.35±0.067	2.61	
PPP	**4 %**	2.95±0.061	2.88±0.055	2.69±0.05	2.51±0.123	2.76	
	8 %	2.83±0.055	2.76±0.117	2.57±0.061	2.39±0.164	2.64	
	12 %	2.64±0.052	2.56±0.049	2.37±0.049	2.2±0.075	2.44	
LPP	**1 %**	2.96±0.071	2.88±0.047	2.71±0.051	2.51±0.082	2.77	
	2 %	2.91±0.053	2.82±0.05	2.64±0.07	2.46±0.061	2.71	
	3 %	2.64±0.052	2.56±0.049	2.37±0.049	2.2±0.075	2.44	
LSD. (Samples) 0.05			**0.099**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 11. Effect of frozen storage period at -18°C on cooking loss (%) of produce beef burger substituted by TPP, PPP and LPP at different levels

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**16.92±0.536**	**18.44±0.214**	**20.2±0.511**	**21.84±0.25**	**19.35**	**0.282**
TPP	**4 %**	15.77±0.2	17.53±0.191	19.71±0.3	20.99±0.172	18.50	
	8 %	15.75±0.252	17.62±0.183	19.72±0.154	20.97±0.165	18.52	
	12 %	15.43±0.21	17.4±0.214	19.53±0.17	20.67±0.236	18.26	
PPP	**4 %**	16.45±0.191	18.02±0.151	20.07±0.097	21.35±0.388	18.97	
	8 %	15.65±0.163	17.58±0.263	19.71±0.146	20.99±0.215	18.48	
	12 %	15.64±0.158	17.83±0.291	19.61±0.144	20.82±0.165	18.48	
LPP	**1 %**	16.21±0.624	17.82±0.176	19.92±0.131	21.23±0.172	18.80	
	2 %	15.69±0.143	17.64±0.303	19.82±0.196	21.15±0.148	18.58	
	3 %	15.54±0.252	17.41±1.297	19.57±0.201	20.83±0.121	18.34	
LSD. (Samples) 0.05			**0.445**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

Table 12. Effect of frozen storage period at -18°C on shrinkage value (%) of produce beef burger substituted by TPP, PPP and LPP at different levels

Level of substitution		Storage period at -18±1°C				mean	LSD. 0.05 (Storage time)
		Zero time	**1st month**	**2nd month**	**3rd month**		
Control sample		**13.72±0.536**	**15.24±0.214**	**17±0.51**	**18.64±0.25**	**16.15**	**0.283**
TPP	**4 %**	12.67±0.200	14.43±0.191	16.61±0.300	17.89±0.172	15.40	
	8 %	12.45±0.252	14.32±0.183	16.42±0.154	17.67±0.165	15.22	
	12 %	12.13±0.21	14.1±0.214	16.23±0.173	17.37±0.236	14.96	
PPP	**4 %**	13.25±0.191	14.82±0.151	16.87±0.097	18.15±0.388	15.77	
	8 %	12.54±0.166	14.48±0.263	16.61±0.146	17.89±0.215	15.38	
	12 %	12.43±0.17	14.63±0.291	16.41±0.144	17.62±0.165	15.27	
LPP	**1 %**	13±0.62	14.62±0.176	16.72±0.131	18.03±0.172	15.59	
	2 %	12.48±0.14	14.44±0.303	16.62±0.196	17.95±0.148	15.37	
	3 %	12.33±0.256	14.21±1.297	16.37±0.201	17.63±0.121	15.14	
LSD. (Samples) 0.05			**0.447**				

TPP: Tomato pomace powder. PPP: Potato peels powder. LPP: Lemon peel powder.

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