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Valorization of tomato peel waste: antioxidant, physicochemical properties and acceptability of dried tomato peel in beef patties

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Abstract

In order to improve the tomato supply chain, tomato peel, a byproduct of the puree and sauce industry, was turned into dried tomato peel (DTP) powder to reduce food manufacturing waste and applied in beef patties as model food. Antioxidant properties, physicochemical properties, and acceptability of beef patties incorporated with DTP waste were determined. Four formulations; control (no DTP), 1.5% DTP, 3.0% DTP and 4.5% DTP were prepared. Antioxidant capacity was measured using 2,2-diphenyl-1-picryl hydrazyl (DPPH) and ferric reducing antioxidant power (FRAP) assay. Meanwhile, physicochemical properties such as pH, colour and texture profile were determined. Consumer's acceptability was determined using a 9-point hedonic scale. The antioxidant capacity was reduced in both DPPH and FRAP assays whereby 3.0% DTP had the highest capacity followed by 4.5% DTP, 1.5% DTP and control. Cooking loss, drip loss, pH, peroxide value and colour of patties decreased as the amount of DTP increased. Texture profile analysis indicated that the addition of DTP significantly increased the hardness, adhesiveness and chewiness, however, there were no significant differences in springiness, cohesiveness, gumminess and resilience. The consumer acceptability test showed that beef patties with 1.5% and 3% DTP had no significant difference with control in terms of colour, taste, juiciness, appearance and overall acceptability. DTP added into beef patties at 3.0% formulation improved the antioxidant capacity. This innovation is useful to reduce waste along the food supply chain.

1. Introduction

Tomatoes or *Solanum lycopersicum* have been widely recognized as rich sources of carotenoids and vitamins, particularly ß-carotene, ascorbic acid, and vitamin C (Mayeaux *et al.,* 2006). The peel and seeds of tomatoes contain highly biologically active compounds such as ß-carotene, lycopene, lutein phytoene and phytofluene (Calvo *et al.,* 2008), which are considered valuable natural compounds and highly demanded by the food, cosmetics and pharmaceuticals industries. The tomato industries, especially in sauces or paste production produced almost 10-30% of waste, whereby peel and seed residues are considered the major by-products (King and Zeidler, 2004). Moreover, tomato industries generate large amounts of by-products and usually are used as animal feed. Numerous studies have been conducted to examine the incorporation of tomatoes and tomato by-products in meat-based products to maintain their properties and improve their health benefits. For instance, in a study conducted by Hussien *et al.* (2019) adding tomato peel powder to chicken sausages helps in reducing microbiological properties and storage stability for 4 months. Tomato paste was also added to frankfurters at 10% and 20% where its antioxidant capacity increased (Valenzuela-Melendres *et al.,* 2014). Another study conducted by Lucia *et al.* (2017) has shown that the addition of tomato peel flour increased the content of carotenoids (lycopene and ß-

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carotene) and dietary fibres in spaghetti which improves the nutritional value of the products themselves.

As for the meat and its associated products, there are common problems which affect the quality of meat itself which is oxidation. It occurs under postmortem conditions and it is unavoidable during processing (Bekhit *et al.,* 2013). This oxidation can change the colour of pigments and lipids caused by biochemical changes in meat. The red colour will deteriorate and undesirable flavours and rancidity will develop, subsequently reducing consumer appeal and satisfaction. Most industries usually add synthetic antioxidants, such as butylated hydroxytoluene (BHT), to delay, retard, or prevent lipid oxidation of meat by scavenging peroxyl radicals or suppressing the formation of free radicals (Shahidi, 2016). However, due to concern over the safety of these synthetic compounds, there are demands to search for natural compounds as antioxidants that can delay the oxidative degradation of lipids, improve quality, and maintain the nutritional value of meat and meat products.

Although studies related to the incorporation of antioxidants from by-products were done previously, there is a paucity of information on the addition of dried tomato peel in beef patties. In addition, the active compound from tomato peel may deliver the effect of antioxidants but could also affect the quality of the beef patties. Therefore, this work aimed to determine the effect of incorporating DTP on the antioxidant, physicochemical as well as sensory properties of beef patties. The results could be beneficial to tomato industries as the active compounds from tomato peel could be an added value to the industry and increase the sustainability of food ingredients while minimizing food waste.

2. Materials and methods

2.1 Preparation for dried tomato peel

Tomatoes (Sweet Million variety) of the maturity index 5 (light red) were purchased from a local supermarket, Shah Alam, Selangor, and were stored at a refrigerated temperature (5±1°C). It proceeded with sample preparation on the following day. Tomatoes were blanched for 1 min and immediately transferred to a bowl of ice water. When the tomatoes were cool enough to handle, the tomato skins were hand-peeled and subjected to freeze-dried using a freeze dryer (Alpha 1-4, Martin Christ, Germany). The DTP was grounded and stored at -20°C until further use. The dried samples were divided into two portions, whereby the first portion was used for antioxidant determination of DTP and the second portion was incorporated into beef patties, cooked and analyzed.

2.3 Preparation of beef patties

A beef chuck cut was obtained from a local supermarket, Section 15, Shah Alam, Malaysia. The beef meat was sampled mainly from both hind legs of the carcass of cows. The experimental samples for each trial were taken from the pooled deboned meat of the carcass. The samples were frozen at -18°C till further use. The samples were used when the meat reached 4°C. After thawing. Four formulations of beef patties were prepared. One formulation was used as a control while the other three formulations were prepared with different ratios of DTP as shown in Table 1. Firstly, texturized vegetable protein (TVP) was ground and mixed with lukewarm water and left for 15 mins. Frozen meat was thawed, minced in the food processor (Panasonic Mk-5087m, Malaysia) and subsequently mixed with ice water, TVP mixture, salt, sugar, white pepper, and DTP for 5 mins in food processor (Panasonic Mk-5087m, Malaysia). Throughout the procedure, the temperature was controlled at less than 10°C. The mixture was then shaped using a patty maker to obtain approximately 100 g and 1 cm thick patties. The patty was then covered with plastic to avoid sticking to each other and vacuum packed and stored at -4°C before further analysis. For cooked beef patties analysis, patties were cooked in a preheated oven at approximately 180°C for 2 mins, then turned over and cooked for another 2 mins (García *et al.,* 2009).

Table 1. Formulations of beef patties incorporated with different percentages of DTP.

Materials	Control (0% DTP)	F1 (1.5%)	F2 (3%)	F3 (4.5%)
Meat	75%	75%	75%	75%
DTP	0%	1.5%	3.0%	4.5%
Texturised vegetable protein (TVP)	5%	3.5%	2%	0.5%
Salt	1.2%	1.2%	1.2%	1.2%
Sugar	1.8%	1.8%	1.8%	1.8%
White pepper	1%	1%	1%	1%
Garlic powder	1%	1%	1%	1%
Ice water	15%	15%	15%	15%

2.4 Extraction of antioxidant compound

Approximately 1 g of the DTP samples (control) was mixed with 75 mL of acetone and 60 mL of petroleum ether (65-100°C) and blended for 5 mins. While for frozen patties, 30 g of frozen patties samples were needed and proceeded with extraction. The mixture was then transferred to a 500 mL separatory funnel. A 9 cm funnel loosely plugged with glass wool and a wash bottle containing acetone facilitated this transfer and prevented the solids from entering the funnel. The extract was

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washed three times with distilled water. The funnel was then shaken gently in an inverted position for 30 s. This step removed the acetone whose function was to remove the water in the sample, thus helping to prevent the formation of stable emulsions. Next, the lower phase was discarded. The hyper phase was then mixed with 20 mL of 90% methanol for 30 s and the hypo phase was discarded. The hyper phase was then mixed with 20 mL of 20% KOH in methanol for 30 seconds and the lower phase was discarded (saponification). The 90% methanol was added and finally, the extract was washed three times with 100 mL of distilled water. The mixture was then diluted with petroleum ether to 100 mL volume. Samples were analyzed immediately or refrigerated in darkness at 0°C for a maximum of 72 hrs (Goula and Adamopoulos, 2005).

2.5 Antioxidant activities measurement (DPPH Free radical scavenging assay and ferric reducing antioxidant power)

Two, 2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay was conducted according to the method as in Saeed *et al.* (2012). The DPPH reagent was prepared by dissolving 24 mg DPPH in 100 mL ethanol and kept in a refrigerator until further use. In a test tube, 3 mL DPPH solution was mixed with 100 µL sample extract (1 mg/mL) or the standard solution. The absorbance was measured using UV-Vis Spectrophotometer (Helios-α, Thermo Scientific, UK) at 517 nm after 30 mins of incubation at room temperature. All tests were carried out in triplicate and values were presented as means of triplicate analyses. Standard (ascorbic acids) was prepared at various concentrations (200-1000 ppm) in triplicate. The radical scavenging activities (AA) of the samples were calculated as percentages of inhibition according to the following equation:

$$AA(\%) = \frac{Abs_{control} - \text{Abs}_{\text{sample}}}{Abs_{control}} \times 100 \quad (1)$$

Meanwhile, the ferric-reducing antioxidant power (FRAP) assay was conducted according to the method described by Babu *et al.* (2013). The FRAP reagent was prepared by mixing 25 mL of 300 mM acetate buffer (pH 3.6), 2.5 mL 10 mM tripyridyl triazine (TPTZ) solution and 2.5 mL of 20 mM ferric chloride hexahydrate ($FeCl_3.6H_2O$). The mixtures were heated to warm at 37℃ for 15 mins before analysis. Next, 2.85 mL of freshly prepared FRAP reagent was mixed into 100 µL of sample extract. Then, the mixtures were incubated at room temperature for 30 mins. The absorbance was measured using UV-Vis Spectrophotometer (Helios-α, Thermo Scientific, England) at 595 nm. A standard curve was made with Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2- carboxylic acid) at 200-1000 ppm. The FRAP values were expressed as milligram Trolox Equivalent per mL sample and values are presented as means of triplicate analysis.

2.6 Physicochemical properties of beef patties

2.6.1 pH values

The pH values were determined in raw and cooked patties using a pH meter (Hanna instrument, HI 2211 pH/ORP meter). The pH is measured in a homogenate prepared with 1 g of patties and 9 mL of distilled water (García *et al.,* 2009).

2.6.2 Colour

The colour determination of the sample was conducted by using Chroma Meter (CR-400, Konica Minolta, Japan) using the colour system CIE L*a*b*system. The instrument was calibrated with a white colour standard. The parameter that was determined are L*= 0 (blank) and L*= 100 (white), a*(- a*= greenness and +a*= redness), b*,(- b*= blueness and +b*= yellowness). The samples were analysed in triplicate.

2.6.3 Cooking loss

Prior to cooking, initial masses of samples were recorded. The patties were cooked in a preheated oven at approximately 180°C for 2 mins, then turned over and cooked for another 2 mins (García *et al.,* 2009). Then, cooked patties were left to cool at room temperature. The mass for each cooked patty was measured. The percentage of cooking loss was calculated according to the formula below:

$$Total\ Cook\ Loss\ (TCL\ \%) = \frac{Raw\ mass - cooked\ mass}{raw\ mass} \times 100\% \quad (2)$$

2.6.4 Drip loss

Drip loss was measured by the difference between the weight of complete frozen patties and the weight of the same patties after thawing overnight (Darwish *et al.,* 2013). The percentage of drip loss was measured according to the formula below:

$$Drip\ loss\ (\%) = \frac{Wt._{frozen\ patties} - Wt._{after\ thawing}}{Wt._{frozen\ patties}} \times 100\% \quad (3)$$

2.6.5 Peroxide value

The peroxide value was measured following the official standard method 965.33 (Association of Official Analytical Collaboration [AOAC] International, 2000). Briefly, 5 g of chicken patties were soaked with 200 mL chloroform for 8 hours and then filtered through Whatman No. 4 filter paper. Then, a mixture of filtrate and chloroform/glacial acetic acid (3:2, v/v) was reacted with a saturated potassium iodide solution in the dark.

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The released iodine was titrated with a 0.001 N sodium thiosulfate solution, and the peroxide value was then expressed as milliequivalents of active oxygen per kilogram of the sample (mEQ O_2/kg).

$$Peroxide\ value = \frac{S \times N \times 1000}{Wt.\ sample} \quad (4)$$

Where S = (Volume titre – Volume blank) mL $Na_2S_2O_3$, and N = normality of $Na_2S_2O_3$

2.6.4 Texture

Texture analysis was conducted by using a computer -assisted Texture Analyser (TTA-XT2i, Stable Micro Systems, UK). The texture profile analysis (TPA) test was used to determine the hardness (N/m^2), cohesiveness, chewiness, springiness (cm/mm) and gumminess (N/cm) of patties. The cylinder probe (P/75) model is attached to the probe detector and the probe weight calibration and load force calibration were carried out. Approximately 2 cm × 2 cm × 2 cm of beef patties were cut and placed at the centre of the platform base for the test. All the samples were analysed in triplicate.

2.7 Acceptability of beef patties

Thirty untrained panellists were randomly selected among students from the Faculty of Applied Science in this evaluation according to the method by the American Meat Science Association (2016). Four samples with different formulations of cooked beef patties, as well as plain water, were given to each panellist. The evaluations were assessed on colour, aroma, taste, juiciness, appearance and overall acceptability by using a 9-point Hedonic scale. The hedonic scale ranged from 1 (dislike extremely) to 9 (like extremely).

2.8 Statistical analysis

All statistics were expressed as mean ± standard deviation (SD). Data were analyzed using one-way ANOVA using MINITAB 17 (v.17, Minitab Inc., State College, PA, USA). Duncan's multiple-range test was used to evaluate the differences between means. A significant difference was measured at the level of $p<0.05$.

3. Results and discussion

3.1 Antioxidant activity of dried tomato peel

The antioxidant capacity of DPPH radical is considered a valid and simplest method for determining the antioxidant ability of the compound. The comparison of antioxidant activity among samples is presented in Figure 1. This assay allows the comparison of the antioxidant potential of ascorbic acid with those present in DTP extract. From the results, all tested samples show significant differences in their antioxidant potential. The extracted DTP shows the highest scavenging activity of 51.20±0.04%. Meanwhile, among patties, 3.0% DTP shows the highest value followed by 4.5% DTP, 1.5% DTP and control. This shows that the gradient increase in the amounts of added DTP powders caused a proportional increase in the antioxidant activity, although 4.5% DTP has a slightly lower percentage of scavenging activity compared to 3.0% DTP. Scavenging activity can be related to the presence of phenolic compounds (Babu *et al.,* 2013). The increase in scavenging activity in beef patties might be due to the high content polyphenols of in tomato peels, which was in agreement with Ammar and Aboalfa (2017). Lasunon *et al.* (2021) also determined the antioxidant activity and antioxidant compound in tomato industrial waste and found the percentage of scavenging activity in hydrophobic fractions was above 60%.

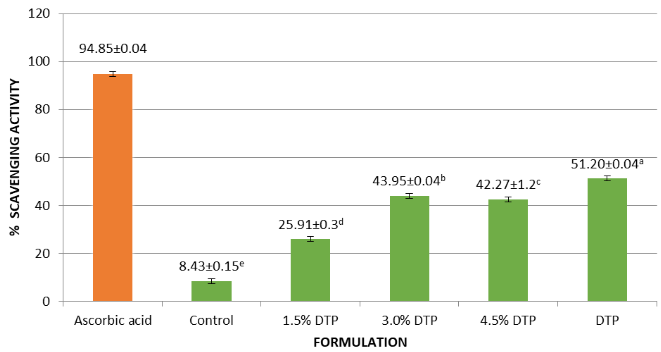

Figure 1. Percentage of scavenging activity of DTP and beef patties incorporated with DTP. Values are presented as mean±SD. Values with different superscripts are statistically significantly different (P<0.05).

On the other hand, FRAP assay is a method that uses antioxidants as reductants in a redox-linked calorimetric reaction. This FRAP assay involved the use of an easily reduced oxidant which is Fe (III). It is a simple method that is used to assess the 'antioxidant power' based on the measurement of the ability of the substance to reduce ferric tripyridyltriazine complex (Fe^{3+}) to ferrous-(2,4,6-tripyridyl-s-triazine), Fe^{2+}. The reaction can be observable through the colour change from colourless Fe^{3+} to a blue complex of Fe^{2+}. Figure 2 shows the standard curve graph for FRAP assay measured at 595 nm with Trolox as standard. FRAP value for each sample expressed as mg TE/ mL was calculated.

From the results, all samples showed significant differences at $p<0.05$. It can be observed that the extracted DTP shows the highest reducing potential of 18.35 mg Trolox equivalent/ mL followed by 3.0% DTP, 4.5% DTP, 1.5% DTP and control. The results were observed to be in a similar pattern with DPPH % scavenging activity whereby there was a gradient increase in the amounts of added DTP. However, recent

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studies conducted have found that the FRAP value of freeze-dried tomatoes ranged from 40-83 µmol Trolox equivalent/g (Ou *et al.,* 2002). The difference in values as compared to the literature may be due to differences in the ripeness of fruits, extraction methods or different fractions of tomato. The study used whole tomatoes for antioxidant analysis and extracted them using acetone and water meanwhile for this analysis, tomato peel fractions were used and extracted using petroleum ether and acetone solvent.

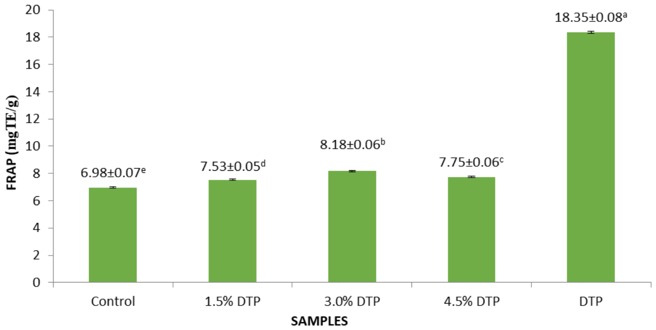

Figure 2. FRAP (mg TE/mL) of DTP and beef patties incorporated with DTP. Values are presented as mean±SD. Values with different superscripts are statistically significantly different (P<0.05).

3.2 The effect of dried tomato peel on the physicochemical properties of beef patties

Measurement of pH on beef patties and DTP were conducted at 25°C and the results were recorded in Table 2. The pH value of raw control patties was 5.73±0.005. The incorporation of DTP on beef patties shows a significant decrease in the pH values ($p<0.05$) in a gradient-decreasing manner. The highest pH value was observed to be raw control patties followed by 1.5% DTP, 3.0% DTP and 4.5% DTP. The pH decrease might be due to the low pH values of dry tomato peel added, which showed to have a pH value of 4.50±0.01. A study conducted by Candogan (2002) and Deda *et al.* (2007) also showed a decrease in pH values when they added tomato paste to several meat products such as beef patties and frankfurter. The low acidity of the 4.5% DTP batch could be one of the reasons for its lower overall acceptability compared to other samples.

Table 2. pH value in beef patties incorporated with dried tomato peel (DTP).

Sample	pH
Control (0%)	5.73±0.005[a]
1.5% DTP	5.63±0.02[b]
3.0% DTP	5.53±0.01[c]
4.5% DTP	5.43±0.05[d]
DTP	4.50±0.01

Values are presented as mean±SD. Values with different superscripts are statistically significantly different (P<0.05).

3.2.1 Colour

Colour determination was conducted on three different points on beef patties which were on the top, bottom and side of patties. The colours were measured as L*, a*, and b* values. From Table 3, it can be observed that the addition of DTP to patties significantly affected the colour parameter in raw patties ($p<0.05$). The results showed that the L* value was significantly lower and a* and b* significantly higher ($p<0.05$) in batches containing DTP than in control batches. Similar results have been reported by Candogan (2002) where they using beef patties containing tomato paste. It supports the fact that the carotenoid compound is responsible for the red colour, a class of isoprenoid compounds varying from yellow to red color, its addition to meat can shift the colour towards orange, which could explain the increase in a* and b* parameters in batches containing DTP compared to control. The biggest difference between the controls and the DTP batches was observed in a* parameter, where values for all DTP batches were almost two-fold higher than the controls.

Table 3. Changes in colour properties in beef patties incorporated with DTP.

Sample	L*	a*	b*
Control (0%)	52.83±0.16[a]	6.10±0.42[c]	11.73±0.16[d]
1.5% DTP	48.77±0.15[b]	15.52±0.18[b]	15.54±0.21[c]
3.0% DTP	45.09±0.19[c]	19.57±0.54[a]	18.53±0.37[b]
4.5% DTP	45.17±0.23[c]	19.94±0.99[a]	20.85±0.75[a]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different (P<0.05).

3.2.2 Cooking and drip loss

The percentages of cooking loss are presented in Table 4. It can be observed that the cooking loss of patties incorporated with DTP is decreased with an increase in the incorporation level and also DTP batches had lower cooking loss values as compared to control batches. The lowest cooking loss value was recorded for patties containing 4.5% DTP while the highest cooking loss value was recorded for the control treatment. Such results may be due to the fiber components such as pectin, cellulose and lignin of DTP, which could affect the cooking loss of the patties since the pectin component could reduce the water loss during cooking by forming gels as reported by Calvo *et al.* (2008). Similar results were reported by Kang *et al.* (2010) when they applied tomato powder to pork patties. Furthermore, these results were parallel to the drip loss (Table 4) due to the fluids separated by cooking might include the fluids, which were probably separated by the thawing of the frozen burger.

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In general, the cooking loss of a meat product is greatly influenced by its ability to retain moisture and fat during cooking. During cooking, patties tend to shrink due to the denaturation of meat proteins and loss of water and fat will be observed. Kim and Joo (2016) also found that patties shrunk after cooking due to the denaturation of muscle proteins and partly from the evaporation of water and loss of melted fat and juice.

Table 4. Changes in cooking loss and drip loss of beef patties incorporated with DTP.

Sample	Cooking loss %	Drip loss %
Control (0%)	36.40±0.05[a]	0.96±0.02[a]
1.5% DTP	29.50±0.02[b]	0.83±0.06[b]
3.0% DTP	26.66±0.01[c]	0.64±0.05[c]
4.5% DTP	24.73±0.06[d]	0.24±0.03[d]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different (P<0.05).

For drip loss, all samples were thawed overnight and weight samples after thawed were analyzed. Data in Table 4 shows that the percentage of drip loss of all samples significantly differed at p<0.05. It shows that the highest amount of DTP (4.5%) batch has the lowest drip loss percentage of 0.24% compared to other samples. Moreover, it could be noticed that the control sample had the highest significant percentage of drip loss than other treatments. The mechanism of drip loss from meat is influenced by both the pH of the tissue and the amount of space in the muscle cell that allows the water to exist. Generally, when the pH has reached the isoelectric point (pI) of the major proteins, 5.1 to 5.5 the net charge of the protein is zero, which means the numbers of positive and negative charges on the proteins are equal (Álvarez *et al.,* 2019). Hence, the attraction between these positive and negative groups can result in a reduction in the amount of water that the meat can hold. Based on Table 2, the pH value of patties with 4.5% DTP was 5.43, which was close to the isoelectric point of meat. However, due to the presence of fibre components in DTP especially pectin, the amount of water loss can be reduced (Ye, 2018).

3.2.3 Texture

The texture profiles of beef patties were determined by using the texture analyser (TTA-XT2i, Stable Micro Systems, UK). TPA measurements were conducted by applying a compression plate with two-cycle compression tests to 50% of their original height. The results obtained were presented as shown in Table 5. The addition of dry tomato peel (DTP) was observed to cause a significant difference in hardness, adhesiveness and chewiness factors. For certain parameters such as springiness, cohesiveness, gumminess and resilience, all the beef patties were observed to have no significant decrease with the increase in DTP. The increase in DTP significantly increases (p<0.05) the hardness of the beef patties. It can be observed that beef patties incorporated with DTP were significantly different from the control although both 1.5% DTP and 3.0% DTP had no significant difference. The beef patties with 4.5% DTP showed an increase in adhesiveness also related to the increased fibre concentration. Furthermore, other fibre components, such as pectin could be responsible for the increase in chewiness, due to its capacity to form gels. This could explain why 4.5% DTP had a higher value in chewiness compared to other formulations. The increase in hardness and adhesiveness in beef patties could be explained by the presence of fibre in the tomato peel. It has been reported that tomato peel has an acid-detergent fibre content of 299.4 g/100 g of dry matter (Knoblich *et al.,*2005). The main structure of the fibre which is cellulose and lignin could modify the textural properties yielding harder patties. A similar result was observed by Calvo *et al.* (2008) when they added tomato peel to fermented sausages.

3.2.4 Peroxide value

Peroxide value is a redox titrimetric determination of hydroperoxides that are formed during the initial primary stages of oxidation in a sample whereby it is commonly expressed as milliequivalents (mEq) of peroxide per kilogram of the sample. All samples were stored for 7 days of storage before the peroxide value was conducted and the results were presented as shown in Table 6. All tested samples showed significant differences in their peroxide value. The control showed the highest peroxide

Table 5. Changes in textural properties in beef patties incorporated with DTP.

Sample	Hardness (N/m^2)	Adhesiveness	Springiness (cm/mm)	Cohesiveness	Gumminess (N/cm)	Chewiness (N/cm^2)	Resilience
Control (0%)	2103.76±36[c]		0.92±0.03[a]	0.85±0.06[a]	1819.38±43.8[a]	1690.79±46[b]	0.42±0.05[a]
1.5% DTP	2287.79±93[b]		0.96±0.04[a]	0.88±0.06[a]	2020.24±22.1[a]	1962.07±29[ab]	0.45±0.05[a]
3.0% DTP	2927.30±23[b]	-2.571±0.4[b]	0.93±0.04[a]	0.87±0.07[a]	2578.43±41.3[ab]	2416.47±49[ab]	0.47±0.07[a]
4.5% DTP	3756.10±63[a]	-1.008±0.12[a]	0.88±0.05[a]	0.86±0.07[a]	3291.10±81.2[a]	2958.01±89[a]	0.49±0.07[a]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different (P<0.05).

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value followed by 1.5% DTP, 4.5% DTP and 3.0% DTP. This indicated that the gradient increase in the amounts of added DTP caused a proportional decrease in the peroxide value although 4.5% DTP was a slightly higher peroxide value compared to 3.0% DTP. The decrease in peroxide value might be due to the presence of biologically active compounds (β-carotene, lycopene, lutein phytoene and phytofluene) in tomato peel to act as a free radical quencher. As supported by Vokk *et al.* (2014) and Rodriguez-Amaya (2015), carotenoids can prevent the peroxidation process caused by singlet oxygen and peroxyl radicals. This is in agreement with Osterlie and Lerfall (2005) who suggested that the presence of antioxidant compounds in tomatoes will scavenge the peroxyl radical yielding a stable radical. Moreover, Tavakkoli *et al.* (2020) reported that thiobarbituric acid, total volatile basic nitrogen, and peroxide values of trouts fillets treated with the combination of tomato residuum extract, and arabic gum coating enriched with dill essential oil could significantly (p≤.05) extend the shelf life of the fillets.

Table 6. Peroxide value of DTP and beef patties incorporated with DTP.

Sample	Peroxide value (mEq/kg)
Control (0%)	3.04±0.08[a]
1.5% DTP	2.58±0.06[b]
3.0% DTP	2.08±0.04[c]
4.5% DTP	2.54±0.06[b]

Values are presented as mean±SD. Values with different superscripts are statistically significantly different (P<0.05).

3.3 Acceptability of beef patties

Table 7 shows the sensory properties of the beef patties. In general, all batches were observed to score well ranged 4 to 8 for all sensory parameters evaluated. For the colour parameters, the score for 4.5% of batches was significantly lower than other batches (p<0.05). The decrease in score might be due to the patties containing high DTP concentrations showing an increase in the red to orange tone as the amount of carotenoids increased. The increase in this tone produces a colour that is different from those usual conventional beef patties. For the aroma score, there were no significant differences between control and 1.5% DTP batches but significantly differed to 3.0% DTP and 4.5% DTP batches at p<0.05. This could be because volatile compounds formed during cooking masked the tomato odour in beef patties. In the case of juiciness, the value was noticeably lower in batches containing 4.5% DTP. When referring to Table 6, since the value of hardness and chewiness of 4.5% DTP is higher, it was expected for the panellists to score lower on the product. The same results were observed for 4.5% DTP which scored a lower value for both taste and appearance. The taste modifications found in patties containing DTP were caused by the tomato flavour, which produced a taste different from the normal one expected for this meat product. Overall acceptability was significantly higher (p<0.05) for control, 1.5% DTP, 3.0% DTP than for 4.5% DTP. Nevertheless, all samples scored a value higher than 5 for overall acceptability although the 4.5% DTP batches scored the lowest among all samples, which could be a result of the low values obtained for the texture and taste properties. On the other hand, the result of Chinese sausages added with 0.2% tomato powder made from whole tomato showed no significant difference in terms of appearance, taste, texture and overall liking scores compared to the control treatment (with nitrites) (Saksomboon *et al.,* 2020).

Present work was able to show that the DTP is an innovative way for the tomato processing industry to valorize side streams and reduce waste. This effort is in line with several studies that highlighted the importance of tailoring cultivation and processing to meet consumer demands and preferences regarding health and nutrition, thereby adding value to the tomato supply chain, including the production of functional and nutraceutical ingredients from biomass that was previously considered waste (Løvdal *et al.,* 2019). Proposed utilization of tomato side streams and by-products from food processing has been reported previously such as nitrite replacer (Farkhondeh and Hoseini, 2017), colour pigments, antioxidants, thickening agents and several more (Løvdal *et al.,* 2019).

4. Conclusion

The effects of the incorporation of DTP on beef patties were determined in terms of their physicochemical properties, antioxidant activities, and acceptability. Physicochemical properties indicated that beef patties with 4.5% DTP were significantly lower in

Table 7. Acceptability of beef patties incorporated with DTP.

Sample	Colour	Aroma	Taste	Juiciness	Appearance	Overall acceptability
Control (0%)	6.20±1.77[a]	6.60±1.63[a]	6.43±1.57[a]	5.63±1.92[a]	6.20±2.06[a]	6.53±1.92[a]
1.5% DTP	7.00±1.29[a]	6.77±1.28[a]	6.43±1.87[a]	6.30±1.76[a]	6.87±1.53[a]	7.03±1.44[a]
3.0% DTP	6.20±1.52[a]	5.83±1.37[b]	6.27±1.36[a]	8.43±1.12[a]	6.57±1.33[a]	6.40±1.40[a]
4.5% DTP	5.73±1.60[b]	5.40±1.43[b]	5.47±1.33[b]	3.67±1.26[b]	5.80±1.54[b]	5.63±1.32[b]

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different (P<0.05).

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cooking loss, drip loss, and pH. Meanwhile, peroxide value and reddish colour were observed to be significantly lower for 3.0% DTP. The addition of DTP to patties significantly increased the hardness, adhesiveness and chewiness of the patties, while other parameters were not affected. Only DTP samples exhibited significantly high free radical scavenging with DPPH as well as FRAP-reducing power compared to other formulations. Beef patties with 4.5% DTP show significantly low acceptability of colour, aroma, taste, juiciness, appearance and overall acceptability. However, 1.5% and 3.0% DTP patties were well accepted by the panellists similar to the control. Patties with 3% DTP are suggested as the most suitable to be applied in production. The DTP is an inventive technique for the tomato processing sector to valorize side streams and reduce waste, as demonstrated by the current study. This initiative is in line with numerous studies that stressed the significance of improving the tomato supply chain and producing functional and nutraceutical ingredients from biomass that was previously regarded as waste.

Conflict of interest

The authors declare no conflict of interest.

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