Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.53222

Preparation, characterization, and evaluation of antioxidant activity of turmeric flour in chicken patties

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Abstract

This study evaluated the use of turmeric (*Curcuma longa* L.) flour as a natural antioxidant in chicken patties. Patties were prepared with different concentrations of turmeric flour: 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$), and 0.75% ($TC_{0.75\%}$). A "treatment-as-usual" patty with 0.25% sodium erythorbate (SE) was prepared. Turmeric flour showed high contents of carbohydrates (78.12%), phenolic compounds (8.13 mg GAE g^{-1}), and flavonoids (29.68 mg QE $^{g-1}$), as well as high antioxidant activity, determined by DPPH (48.71% inhibition) and FRAP (9.11 mg QE g^{-1}) assays. Patties were analyzed after 1, 15, 30 and 45 days of storage at -18 °C. The addition of turmeric resulted in less reddish, and darker, more yellowish patties. Changes in chemical composition, pH, or shrinkage percentage were not observed. $TC_{0.75\%}$ obtained the highest cooking yield (91.27%). $TC_{0.25\%}$ was the softest, while $TC_{0.75\%}$ and Control had the lowest cohesiveness. Differences in resilience between $TC_{0.25\%}$, $TC_{0.75\%}$, and Control were not observed. Changes in springiness and chewiness were not observed. Turmeric patties showed similar oxidative stability to the SE formulation, differing from Control throughout the entire storage period. Turmeric flour prevented lipid oxidation in chicken patties to the same extent as the synthetic antioxidant, demonstrating potential as a natural antioxidant.

Keywords: phenolic compounds; color; lipid oxidation; texture profile.

Practical Application: Turmeric flour showed great potential as a natural antioxidant in meat products.

1 Introduction

The sensorial characteristics of the burger, combined with its convenient preparation, make it a widely consumed meat product. However, its lipid-rich composition, in conjunction with the meat grinding during the manufacturing process, make patties more susceptible to lipid oxidation, resulting in undesirable flavors and odors, nutritional value loss, and formation of potentially toxic substances (Reddy et al., 2018; Ribeiro et al., 2019).

Aiming to reduce oxidative processes and increase the shelf life of processed foods, the industry utilizes antioxidants, mainly synthetic ones (Serpa Guerra et al., 2020). However, some have been associated with gastrointestinal disorders, food allergies, and carcinogenic effects (Oliveira et al., 2013). Due to these issues, as well as consumers' search for healthier foods, the replacement of synthetic antioxidants with natural antioxidants has been studied (Ribeiro et al., 2019). There are reports of herbs, fruits, and spices used as natural antioxidants, such as olive leaves, oregano, basil, rosemary, and garlic; flaxseed meal; pomegranate peel and bagasse powder (Zhang et al., 2016; Sharma & Yadav, 2020); and turmeric powder (Mancini et al., 2015, 2016; Carvalho et al., 2020; Kilic et al., 2021). These natural antioxidants were utilized in different food matrices, such as bread (Lim et al., 2011) and meat products (Fernandes et al., 2016; Cócaro et al., 2019; Patriani et al., 2021).

Turmeric (*Curcuma longa* L.) is an herbaceous perennial plant native to southern Africa that belongs to the Zingiberaceae family. It is widely used in India and in worldwide cuisine due to its flavor, coloring, and antimicrobial, anti-inflammatory, and antioxidant properties (Hewlings & Kalman, 2017). For preservation purposes, the turmeric rhizome is dehydrated and ground into a powder, rich in carbohydrates and phenolic compounds, such as curcumin. Curcumin eliminates reactive oxygen species, such as hydroxyl radicals, superoxide anions, and singlet oxygen, which are related to cell damage and lipid oxidation (Lim et al., 2011; Sueth-Santiago et al., 2015). Thus, the objective of this study was to elaborate and characterize turmeric flour, as well as to evaluate the effect of its addition in different concentrations in chicken patties.

2 Materials and methods

2.1 Preparation and characterization of turmeric flour

The turmeric (*Curcuma longa* L.) was acquired from a local producer (Londrina-PR, Brazil). To obtain turmeric flour, the rhizomes were selected and washed in water after being sanitized with a 2.5% sodium hypochlorite solution. Afterwards, the roots were ground with the peel in a food processor (Multi Pro All in One 2, Philco, Brazil) and then dried in an air circulating oven (TE-394/2, Tecnal, Brazil) at 50 °C for 7 hours.

Received 02 Aug., 2022
Accepted 25 Oct., 2022
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The dehydrated material was ground again in a coffee grinder (MDR301, Cadence, Brazil) and sieved on a 24-mesh sieve. The turmeric flour obtained was stored in plastic packaging and kept in a dry and ventilated place until the time of analysis.

2.2 Color analysis and proximate composition of turmeric flour

The color was evaluated using a Minolta CR400 colorimeter. The L* (lightness), a* (redness) and b* (yellowness) values were determined by the CIELab system.

The *proximate composition* (moisture, protein, lipid, and ash) was determined according to Association of Official Analytical Chemists (2000) methodologies. The carbohydrate content was determined by difference.

2.3 Evaluation of the antioxidant activity of turmeric flour

Extract preparation

To evaluate antioxidant activity, turmeric extracts were prepared in triplicate based on the methodologies described by Sulaiman et al. (2011) and Sepahpour et al. (2018), with modifications. Turmeric (1.00 g) was added to 20.00 mL of 80% acetone solution and this mixture was stirred at 150 rpm on a shaking table (MA 140/CFT, Marconi, Brazil) for 30 minutes (20 °C). The supernatant was then filtered on a filter paper. The filtering and stirring with acetone solution process was repeated, resulting in a final extract volume of 60.00 mL, with a turmeric concentration of 16.66 mg mL^{-1}.

Antioxidant activity and determination of phenolic and flavonoid compounds in turmeric flour

The antioxidant capacity of turmeric flour was determined by the DPPH assay as described by Sepahpour et al. (2018) and Sulaiman et al. (2011), with adaptations (0.1 mL of the extract at a concentration of 8.33 mg mL^{-1} was mixed with 3.9 mL of 0.1 mmol L^{-1} DPPH solution prepared in methanol, stirred, and left in the dark for 30 min./25 °C). The results were expressed as percent inhibition.

Antioxidant activity was determined by the ferric reducing antioxidant power (FRAP) assay (Sepahpour et al., 2018). Quercetin (QE) was used as a standard and the results were expressed in milligrams of QE equivalent per gram of turmeric (mg QE g^{-1}).

The total phenolic compounds content was determined according to the method from Sepahpour et al. (2018). Gallic acid (GAE) was used as a standard and the results were expressed in milligrams of GAE equivalent per gram of turmeric (mg GAE g^{-1}).

Total flavonoid compounds were determined according to Sepahpour et al. (2018). QE was used as a standard at concentrations of 16 to 400 µg mL^{-1}. The results were expressed in mg QE g^{-1}.

2.4 Preparation and evaluation of chicken patties

Preparation of the chicken patties

The chicken patties were prepared with different concentrations of turmeric flour: 0.00% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$), and 0.75% ($TC_{0.75\%}$). A formulation with 0.25% synthetic antioxidant sodium erythorbate (SE) was also prepared.

The chicken breast (60%) was ground in a food processor (Multi Pro All in One 2, Philco, Brazil), along with the skin (15%). Subsequently, the mechanically deboned meat (15%) and the other ingredients (soy protein isolate 7.8%, water 10%, salt 1.7%, onion powder 0.06%, garlic powder 0.20%, white pepper 0.15%) were added until the mixture was completely homogenized. The patties were shaped into 90 g units (± 10 g), transferred to a tray, wrapped in a plastic bag, and identified with their respective codes. The samples were stored at -18 °C until the time of analysis.

Physicochemical analysis and proximate composition of the patties

Immediately after the patties were prepared, the chemical composition was determined as described in section 2.2. The pH measurements (n=3) were obtained in the lateral region of the samples using a potentiometer equipped with an insertion electrode (Testo 205, Testo, Germany). Cooking yield, shrinkage, color, and texture profile of the patties were analyzed after 1, 15, 30, and 45 days of storage at -18 °C.

For the yield analysis, the samples (n=3) were weighed before and after cooking in an electric pot at 215 °C for 3 minutes on each side with the lid off, and another 3 minutes with the lid on. The cooking yield was expressed as a percentage according to the Equation 1:

$$\%cooking\ yield = 100\% - \left[\left(\frac{IW - FW}{FW}\right) x100\%\right] \quad (1)$$

where IW = initial weight of the sample and FW = final weight of the sample after cooking.

For shrinkage evaluation, a digital caliper was used. The diameter of the samples (n=3) was measured before and after cooking (performed according to yield analysis). The result was expressed in percent shrinkage, according to the Equation 2:

$$\%shrinkage = \left(\frac{di - df}{di}\right) x100\% \quad (2)$$

where d_i = initial diameter and d_f = final diameter.

Color parameters (n=9) were determined using a colorimeter (CR400, Konica Minolta, Japan), with illuminant D65 and 10° observation angle. The L* (lightness), a* (redness) and b* (yellowness) values were determined by the CIELab system.

Texture profile analysis (TPA) was performed (n=6) on a TA-XTplus Texture Analyzer (Stable Micro Systems, UK), with a cylindrical probe (P35), as described by Bourne (1978). The parameters employed were height 50 mm, pre-test speed 5.0 cm min^{-1}, test speed 20.0 cm min^{-1}, post-test speed 10 cm min^{-1}, distance 0.70 cm, and force 0.98 N. After cooking in an electric pan (according to yield analysis), the patties were cut into 1 cm^3 cubes. The parameters evaluated were hardness (N), springiness (mm), cohesiveness, chewiness (N mm), and resilience.

Evaluation of lipid oxidation

The lipid oxidation of the patties (n=4) was evaluated after 1, 15, 30 and 45 days of storage at -18 °C by the thiobarbituric acid reactive substances (TBARS) assay, as described by Tarladgis et al. (1960). The results were expressed in mg of malonaldehyde (MDA) kg^{-1} sample.

2.5 Statistical analysis

The results were analyzed using the *Statistica 7.0* for Windows by analysis of variance (ANOVA), followed by the Tukey test at 5% probability.

3 Results and discussion

3.1 Proximate composition, total phenolic and flavonoids compounds, and antioxidant activity of turmeric

Turmeric flour had a carbohydrate content of 78.12% (Table 1), which is the main component of its matrix. Similar results have been described by other authors, with values ranging from 70 to 76.39% (Lim et al., 2011; Mushtaq et al., 2019; Restrepo-Osorio et al., 2020). The ash, protein, and lipid values were 5.48, 5.20, and 1.22 g 100 g^{-1}, respectively. The moisture content of 9.98% allows the powder obtained to be characterized as flour, meeting the current legislation that requires a maximum value of 15% (Brasil, 2005).

The total phenolic compounds content in turmeric extracts (8.13 mg GAE g^{-1}) (Table 1), were similar to the values found by Soares et al. (2021), of 8.67 mg GAE g^{-1} and Sulaiman et al. (2011), with 7.9 mg GAE g^{-1}. These studies also used acetone as the extracting solvent. The solvent employed is important because the phenolic compounds in turmeric, such as curcumin, are apolar, poorly soluble in water (Jiang et al., 2021).

Turmeric flour showed a total flavonoid compounds of 29.68 mg QE g^{-1} (Table 1). This value was higher than that obtained by Ali et al. (2021), of 4.30 mg QE g^{-1}, who evaluated turmeric extract using a 70% ethanol and 0.1% formic acid solution.

Table 1. Proximate composition, total phenolic and flavonoid compounds content, DPPH and FRAP assays, and turmeric (*Curcuma longa* L.) flour color (L*, a*, and b*).

Parameter	Turmeric flour
Moisture (g 100 g^{-1})	9.98 ± 0.21
Proteins (g 100 g^{-1})	5.20 ± 0.03
Lipids (g 100 g^{-1})	1.22 ± 0.78
Ash (g 100 g^{-1})	5.48 ± 0.19
Carbohydrates (g 100 g^{-1})	78.12 ± 0.15
Total phenolic compounds (mg GAE g^{-1})	8.13 ± 1.12
Total flavonoid compounds (mg QE g^{-1})	29.68 ± 0.83
FRAP (mg QE g^{-1})	9.11 ± 0.70
DPPH (% inhibition)	48.71 ± 3.57
L*	62.34 ± 0.86
a*	11.32 ± 0.31
b*	53.32 ± 1.13

Values expressed as mean ± standard deviation.

By FRAP assay, turmeric flour showed antioxidant activity of 9.11 mg QE g^{-1} (Table 1). Soares et al. (2021) found similar values (10.09 mg QE g^{-1}) for commercial organic turmeric powder, while Sepahpour et al. (2018) reported higher values (85.0 mg QE g^{-1}) for resuspended freeze-dried turmeric extract. This result is expected since the dried extract was employed instead of the crude filtrate.

By the DPPH method, the antioxidant activity was 48.71% inhibition (Table 1). This value is twice as high as those obtained by Soares et al. (2021) for conventionally dried commercial organic turmeric (*Curcuma longa* L.) powder. Possibly, oven drying turmeric at a low temperature (50 °C) preserved the antioxidant compounds.

Regarding color, the turmeric flour was yellowish (b*=53.32) and dark (L*=62.34) (Table 1), probably due to the incorporation of the peel in its preparation.

3.2 Evaluation of the chicken patties

The raw chicken patties showed adequate approximate chemical composition (Table 2). All formulations met the requirements demanded by Brazilian legislation (Brasil, 2000), with fat values below 23%, protein values above 15%, and total carbohydrate values below 3%.

Moisture, protein, and ash contents did not differ ($p>0.05$) among formulations. $TC_{0.50\%}$ showed the highest lipid content, followed by $TC_{0.25\%}$ which did not differ from the rest. Probably, the higher lipid content was due to intrinsic variations of the raw materials used since turmeric flour is not rich in lipids.

Regarding pH, no differences ($p>0.05$) were observed between the formulations. The values ranged from 6.00 to 6.11 (Table 2).

Regarding cooking yield (Table 3), on day 1, the Control formulation showed the lowest yield ($p<0.05$), while SE and $TC_{0.50\%}$ obtained the highest values. In the periods of 15, 30, and 45 days, $TC_{0.75\%}$ yield values were greater or equal to the other formulations, while Control showed lower yields ($p<0.05$). Probably, the addition of turmeric flour increased the yield because of its high carbohydrate content. It is possible that the soluble fibers of the flour, due to their gel-forming ability, positively contributed to the stability of the final patty, and its water holding capacity (Cócaro et al., 2019).

After 30 days of storage, aside from $TC_{0.75\%}$, all formulations showed a reduction in yield when compared to the initial periods (1 and 15 days). After 45 days, however, no reduction was observed.

As for the percent shrinkage of the patties, there was no difference ($p>0.05$) between the formulations (Table 3), nor the storage times – except for the Control formulation, which showed greater shrinkage on the 30th day of storage.

Regarding color, $TC_{0.75\%}$ was darker than SE on the first day but did not differ from the Control and the other formulations with turmeric flour (Table 4). Mancini et al. (2015) found similar L* values (54.15), when evaluating rabbit patties with 3.5% turmeric; as did Karpińska-Tymoszczyk & Draszanowska

Table 2. Proximate composition, pH of raw chicken patties prepared with 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$), and 0.75% ($TC_{0.75\%}$) of turmeric (*Curcuma longa* L.) flour, and 0.25% of sodium erythorbate (SE).

Parameter	Chicken patty formulation				
	Control	SE	$TC_{0.25\%}$	$TC_{0.50\%}$	$TC_{0.75\%}$
Moisture (g 100 g^{-1})	71.13^{a} ± 0.30	71.16^{a} ± 0.50	69.81^{a} ± 0.59	69.60^{a} ± 0.79	70.66^{a} ± 0.61
Proteins (g 100 g^{-1})	15.64^{a} ± 0.42	15.92^{a} ± 0.37	16.00^{a} ± 0.72	16.02^{a} ± 1.45	16.02^{a} ± 0.46
Lipids (g 100 g^{-1})	9.59^{a} ± 0.29	9.34^{a} ± 0.57	10.10^{ab} ± 0.85	10.98^{b} ± 0.70	9.53^{a} ± 0.72
Ash (g 100 g^{-1})	2.69^{a} ± 0.01	2.71^{a} ± 0.06	2.74^{a} ± 0.14	2.80^{a} ± 0.05	2.78^{a} ± 0.04
Carbohydrates (g 100 g^{-1})	0.94^{a} ± 0.15	0.87^{a} ± 0.59	1.35^{a} ± 0.42	1.34^{a} ± 1.97	1.01^{a} ± 0.20
pH	6.10^{a} ± 0.05	6.07^{a} ± 0.04	6.00^{a} ± 0.09	6.04^{a} ± 0.05	6.11^{a} ± 0.03

Values expressed as mean ± standard deviation (n=3). $^{a-b}$ Means followed by different lowercase letters in the same row differ significantly by the Tukey test ($p<0.05$).

Table 3. Percent cooking yield and shrinkage of chicken patties after cooking at 215 °C prepared with 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$) and 0.75% ($TC_{0.75\%}$) of turmeric (*Curcuma longa* L.) flour and 0.25% of sodium erythorbate (SE).

Parameter	Period (days)	Chicken patty formulation				
		Control	SE	$TC_{0.25\%}$	$TC_{0.50\%}$	$TC_{0.75\%}$
Cooking yield (%)	1	83.61^{dA} ± 0.45	88.92^{abA} ± 0.67	86.81^{cA} ± 0.41	89.45^{aA} ± 0.52	87.47^{bcA} ± 0.48
	15	83.66^{bA} ± 0.98	84.39^{bB} ± 0.50	86.63^{abA} ± 0.66	88.26^{aAB} ± 0.81	86.02^{abA} ± 1.43
	30	73.80^{bB} ± 0.58	74.92^{abC} ± 0.80	78.11^{abC} ± 1.41	79.81^{abC} ± 1.07	84.34^{aA} ± 7.01
	45	83.89^{bcA} ± 0.72	82.87^{cB} ± 1.16	82.13^{cB} ± 0.32	87.11^{bB} ± 0.23	91.27^{aA} ± 0.72
Shrinkage (%)	1	12.92aA± 0.84	13.35^{aA} ± 0.97	13.53^{aA} ± 1.86	13.06^{aA} ± 1.07	11.35^{aA} ± 0.82
	15	13.93^{aA} ± 0.30	13.06^{aA} ± 1.15	13.46^{aA} ± 1.93	12.84^{aA} ± 1.18	13.20^{aA} ± 0.86
	30	15.97^{aB} ± 0.42	15.74^{aA} ± 0.94	15.99^{aA} ± 1.39	15.16^{aA} ± 0.50	13.10^{aA} ± 2.79
	45	13.31^{aA} ± 0.99	13.30^{aA} ± 1.41	14.87^{aA} ± 1.08	14.64aA± 1.03	11.35^{aA} ± 0.57

Values expressed as mean ± standard deviation (n=3). $^{a-c}$ Means followed by different lowercase letters in the same row differ significantly by the Tukey test ($p<0.05$). $^{A-C}$ Means followed by different capital letters in the same column differ significantly by the Tukey test ($p<0.05$).

Table 4. Color parameters L*, a* and b* of raw chicken patties prepared with 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$) and 0.75% ($TC_{0.75\%}$) of turmeric (*Curcuma longa* L.) flour and 0.25% of sodium erythorbate (SE). During storage at -18 °C for 1, 15, 30 and 45 days.

Parameter	Period (days)	Chicken patty formulation				
		Control	SE	$TC_{0.25\%}$	$TC_{0.50\%}$	$TC_{0.75\%}$
L*	1	57.30^{abA} ± 3.37	58.25^{aA} ± 1.18	57.07^{abA} ± 1.83	56.11^{abA} ± 1.88	54.51^{bA} ± 2.33
	15	56.12^{aA} ± 1.14	56.75^{aA} ± 1.85	55.23^{abAB} ± 1.83	53.60^{bB} ± 1.59	54.48^{abA} ± 2.60
	30	55.56^{abA} ± 1.66	56.31^{aA} ±1.85	54.49^{bcB} ± 1.94	53.09^{cB} ± 0.42	54.58^{bcA} ± 0.83
	45	57.44^{aA} ± 0.87	54.38^{bB} ± 1.65	54.21^{bB} ± 1.16	54.31^{bB} ± 0.64	54.64^{bA} ± 1.06
a*	1	6.14^{bA} ± 1.17	7.72^{aA} ± 1.09	5.33^{bcA} ± 0.84	4.18^{cdAB} ± 0.65	3.75^{dA} ± 0.97
	15	6.12^{bA} ± 0.42	7.41^{aA} ± 1.17	4.37^{cAB} ± 0.72	3.12^{cB} ± 0.38	4.06^{cA} ± 0.99
	30	5.48^{bA} ± 0.26	7.40^{aA} ± 0.48	4.83^{bcAB} ± 0.53	4.76^{bcA} ± 0.76	4.29^{cA} ± 0.99
	45	6.62^{aA} ± 1.07	6.71^{aA} ± 0.82	3.94^{bB} ± 1.27	3.96^{bAB} ± 0.90	3.92^{bA} ± 0.89
b*	1	11.84^{bA} ± 2.12	13.65^{bA} ± 1.44	20.24^{aA} ± 0.80	22.18^{aA} ± 2.96	22.94^{aA} ± 2.05
	15	11.30^{cA} ± 1.61	12.73^{cA} ± 0.94	17.16^{bB} ± 1.33	20.25^{aAB} ± 2.05	22.42^{aA} ± 2.24
	30	10.24^{cA} ± 1.64	12.84^{cA} ± 1.98	17.02^{bB} ± 1.99	19.46^{abAB} ± 2.94	21.95^{aA} ± 3.45
	45	11.65^{cA} ± 1.17	10.16^{cB} ± 2.19	15.47^{bB} ± 2.57	18.80^{aB} ± 2.09	21.00^{aA} ± 2.93

Values expressed as mean ± standard deviation (n=9). $^{a-d}$ Means followed by different lowercase letters in the same row differ significantly by the Tukey test ($p<0.05$). $^{A-B}$ Means followed by different capital letters in the same column differ significantly by the Tukey test ($p<0.05$).

(2019), who obtained L* of 59.21 for chicken meatballs prepared with sodium erythorbate.

On the 15th day of storage, $TC_{0.50\%}$ was lighter than the Control and SE formulations. However, at 30 days, the turmeric formulations were the darkest. At 45 days, all samples, except the Control, showed L* around 54 and did not differ ($p>0.05$). In general, the addition of turmeric flour contributed to the browning of the patties, due to the color of the flour itself (Table 1).

For the a* parameter, $TC_{0.25\%}$, $TC_{0.50\%}$ and $TC_{0.75\%}$ showed lower results ($p<0.05$) when compared to the Control and SE formulations at all analyzed times, indicating a less reddish color. Similar results were found by Kilic et al. (2021), who evaluated raw chicken meatballs with 0.5% of turmeric. This is due to the low a* value of the flour.

Regarding the b* parameter, $TC_{0.25\%}$, $TC_{0.50\%}$, and $TC_{0.75\%}$, were more yellowish ($p<0.05$) than the Control and SE formulations.

Kilic et al. (2021) obtained higher average b* values (26.75) than those obtained in the present study, when evaluating raw chicken meatballs with 1% turmeric - probably due to the higher concentration of turmeric added. Over the storage time, small variations in color were observed, solely $TC_{0.75\%}$ did not vary.

The texture profiles of the chicken patties after cooking at 215 °C are presented in Table 5. Regarding the hardness parameter, $TC_{0.25\%}$ was the softest from day 1 to day 30 of storage. SE was the second softest on the 1st and 15th day. On day 45, however, there was no difference ($p>0.05$) between the formulations. Up to 30 days of storage, springiness did not differ between the formulations. At 45 days, $TC_{0.50\%}$ was less springy than the others.

When compared to the other texture parameters, cohesiveness was higher ($p<0.05$) in the SE and $TC_{0.25\%}$ formulations, while $TC_{0.75\%}$ and Control had the lowest values. Regarding the chewiness parameter, there was no difference between the formulations, demonstrating that this important texture parameter was not altered by turmeric flour. For patties treated with pomegranate peel and bagasse powder, Sharma & Yadav (2020) had observed increases in chewiness values. The highest resilience was observed in SE throughout the entire storage period. $TC_{0.25\%}$ and $TC_{0.75\%}$ showed similar values to the Control formulation. At 45 days, all formulations showed similar resilience values.

Regarding lipid oxidation, Control showed greater oxidation in comparison with the other formulations on days 1, 30, and 45 (Table 6), confirming the importance of the use of antioxidants in the preparation of patties. At day 1 of storage, the SE formulation did not differ from $TC_{0.25\%}$ and $TC_{0.50\%}$, showing approximately 1.9 times lower TBARS values than the Control. $TC_{0.75\%}$ showed the lowest lipid oxidation value, more than 2 times lower than Control.

On day 15 of storage, differences between the formulations were not observed, probably due to the large standard deviation obtained for the Control formulation. On day 30 of storage, the Control formulation was 6 times more oxidized than the SE and turmeric formulations, demonstrating that turmeric acted as an antioxidant, similarly to sodium erythorbate. On the 45th day of storage, SE and $TC_{0.75\%}$ did not differ, and had the lowest TBARS

Table 5. Texture profile analysis (TPA) of chicken patties after cooking at 215 °C prepared with 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$) and 0.75% ($TC_{0.75\%}$) of turmeric (*Curcuma longa* L.) flour and 0.25% of sodium erythorbate (SE), during storage at -18 °C for 1, 15, 30 and 45 days.

Parameter	Period (days)	Control	SE	$TC_{0.25\%}$	$TC_{0.50\%}$	$TC_{0.75\%}$
Hardness (N)	1	$12.40^{aB} \pm 1.77$	$10.39^{bcB} \pm 1.34$	$9.35^{cB} \pm 1.11$	$11.56^{abB} \pm 0.48$	$12.47^{aA} \pm 0.71$
	15	$15.62^{aA} \pm 2.33$	$11.14^{bcB} \pm 0.51$	$9.26^{cB} \pm 0.81$	$14.93^{aA} \pm 2.63$	$11.97^{bAB} \pm 0.65$
	30	$11.73^{bB} \pm 1.19$	$14.9a^{aA} \pm 2.20$	$9.63^{cB} \pm 1.07$	$12.47^{bAB} \pm 1.42$	$11.12^{bcB} \pm 1.02$
	45	$11.59^{aB} \pm 0.84$	$12.04^{aB} \pm 1.66$	$11.69^{aA} \pm 1.31$	$12.47^{aB} \pm 2.31$	$10.06^{aC} \pm 0.62$
Springiness (mm)	1	$6.41^{aA} \pm 0.10$	$6.45^{aA} \pm 0.04$	$6.45^{aA} \pm 0.06$	$6.41^{aA} \pm 0.08$	$6.37^{aA} \pm 0.08$
	15	$6.39^{aA} \pm 0.06$	$6.46^{aA} \pm 0.03$	$6.41^{aA} \pm 0.09$	$6.38^{aA} \pm 0.09$	$6.41^{aA} \pm 0.06$
	30	$6.33^{aA} \pm 0.06$	$6.42^{aA} \pm 0.06$	$6.43^{aA} \pm 0.07$	$6.10^{bB} \pm 0.18$	$6.38^{aA} \pm 0.10$
	45	$6.38^{abA} \pm 0.08$	$6.45^{aA} \pm 0.04$	$6.41^{aA} \pm 0.08$	$6.27^{bAB} \pm 0.10$	$6.42^{aA} \pm 0.06$
Cohesiveness	1	$0.87^{dB} \pm 0.02$	$1.00^{aA} \pm 0.03$	$1.01^{aA} \pm 0.02$	$0.96^{bA} \pm 0.02$	$0.91^{cB} \pm 0.01$
	15	$0.89^{cB} \pm 0.01$	$0.97^{aA} \pm 0.02$	$0.95^{abB} \pm 0.05$	$0.88^{cB} \pm 0.03$	$0.92^{bcAB} \pm 0.01$
	30	$0.89^{abB} \pm 0.01$	$0.86^{bB} \pm 0.02$	$0.91^{aB} \pm 0.03$	$0.85^{bB} \pm 0.03$	$0.87^{abC} \pm 0.04$
	45	$0.95^{abA} \pm 0.02$	$0.99^{aA} \pm 0.03$	$0.92^{bB} \pm 0.02$	$0.97^{abA} \pm 0.05$	$0.95^{abA} \pm 0.02$
Chewiness (N mm)	1	$69.99^{aA} \pm 3.41$	$62.96^{aA} \pm 3.58$	$61.32^{aA} \pm 8.40$	$70.93^{aA} \pm 1.70$	$70.93^{aA} \pm 5.59$
	15	$74.28^{aA} \pm 10.09$	$69.84^{aA} \pm 3.81$	$63.13^{aA} \pm 4.38$	$73.75^{aA} \pm 8.08$	$69.23^{aA} \pm 3.93$
	30	$65.86^{aA} \pm 3.04$	$75.78^{aA} \pm 12.73$	$62.04^{aA} \pm 2.92$	$69.71^{aA} \pm 7.55$	$62.33^{aA} \pm 1.82$
	45	$68.62^{aA} \pm 5.29$	$67.27^{aA} \pm 5.11$	$67.62^{aA} \pm 6.50$	$70.56^{aA} \pm 13.97$	$61.98^{aA} \pm 2.86$
Resilience	1	$0.44^{bcA} \pm 0.01$	$0.48^{aA} \pm 0.02$	$0.45^{abcA} \pm 0.03$	$0.46^{abA} \pm 0.01$	$0.42^{cA} \pm 0.02$
	15	$0.43^{bA} \pm 0.01$	$0.46^{aA} \pm 0.01$	$0.43^{bAB} \pm 0.02$	$0.42^{bB} \pm 0.01$	$0.43^{bA} \pm 0.02$
	30	$0.40^{bcB} \pm 0.01$	$0.43^{aB} \pm 0.02$	$0.41^{abB} \pm 0.01$	$0.39^{cdC} \pm 0.00$	$0.38^{dB} \pm 0.01$
	45	$0.44^{abA} \pm 0.01$	$0.45^{aAB} \pm 0.02$	$0.42^{bAB} \pm 0.01$	$0.45^{aA} \pm 0.02$	$0.44^{abA} \pm 0.01$

Values expressed as mean ± standard deviation (n=6). a-d Means followed by different lowercase letters in the same row differ significantly by the Tukey test ($p<0.05$). A-C Means followed by different capital letters in the same column differ significantly by the Tukey test ($p<0.05$).

Table 6. Lipid oxidation values (mg malonaldehyde kg^{-1} sample) of raw chicken patties prepared with 0% (Control), 0.25% ($TC_{0.25\%}$), 0.50% ($TC_{0.50\%}$) and 0.75% ($TC_{0.75\%}$) of turmeric (*Curcuma longa* L.) flour and 0.25% of sodium erythorbate (SE), during storage at -18 °C for 1, 15, 30 and 45 days.

Period (days)	Control	SE	$TC_{0.25\%}$	$TC_{0.50\%}$	$TC_{0.75\%}$
1	$0.47^{aB} \pm 0.02$	$0.27^{bB} \pm 0.01$	$0.27^{bA} \pm 0.03$	$0.23^{bcB} \pm 0.02$	$0.21^{cC} \pm 0.03$
15	$0.51^{aB} \pm 0.20$	$0.28^{aB} \pm 0.05$	$0.40^{aA} \pm 0.09$	$0.42^{aAB} \pm 0.05$	$0.35^{aAB} \pm 0.01$
30	$2.52^{aA} \pm 0.17$	$0.38^{bA} \pm 0.07$	$0.48^{bA} \pm 0.04$	$0.45^{bAB} \pm 0.06$	$0.36^{bA} \pm 0.05$
45	$1.27^{aB} \pm 0.64$	$0.33^{bAB} \pm 0.01$	$0.62^{abA} \pm 0.34$	$0.59^{abA} \pm 0.28$	$0.28^{bB} \pm 0.01$

Values expressed as mean ± standard deviation (n=4). a-c Means followed by different lowercase letters in the same row differ significantly by the Tukey test ($p<0.05$). A-B Means followed by different capital letters in the same column differ significantly by the Tukey test ($p<0.05$).

values when compared to the rest. Mancini et al. (2016) also found lower TBARS values for rabbit patties cooked with 3.5% turmeric (0.13 mg kg^{-1}) and 0.1% ascorbic acid (0.18 mg kg^{-1}) when compared to the control (0.30 mg kg^{-1}). The use of turmeric also prevented the increase in TBARS values in chicken meatballs (0.17 *versus* 0.39 mg MDA kg^{-1}), when compared to the control (Kilic et al., 2021).

Evaluating the storage time, TBARS values increased up to 30 days in all formulations. This showed that this period had the maximum peak of MDA formation, and subsequently the oxidation values were reduced with the decomposition of this compound, this behavior can occur in some products from lipid oxidation (Channon & Trout, 2002), due to secondary reactions of malonaldehyde, as observed by Savoldi et al. (2021) in Brazilian sausage. After 30 days of storage, the control formulation showed higher TBARS values than the human detection threshold of 2 mg MDA kg^{-1} (Campo et al., 2006), making the rancid taste and aroma perceptible to consumers.

The lipid oxidation results suggest that turmeric flour has similar antioxidant activity to sodium erythorbate, showing great potential for replacing this synthetic antioxidant without changes in chemical composition, shrinkage, and texture profile.

4 Conclusion

Turmeric flour showed high content of carbohydrates (78.12%), flavonoids (29.68 mg QE g^{-1}), and total phenolic compounds (8.13 mg GAE g^{-1}), as well as antioxidant activity. The use of turmeric flour as a substitute for synthetic antioxidants in chicken patties resulted in a meat product with no changes in chemical composition or texture profile, improved cooking yield and oxidative stability similar to the synthetic antioxidant.

Acknowledgements

The authors thank the Academic Writing Center of UEL for assistance with English language translation and developmental editing.

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