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ARTICLE

Quality Properties and Storage Characteristics of Pyeonyuk with Different Additional Levels of Turmeric Powder

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Abstract The composition of turmeric powder (TP) can affect the quality properties and storage characteristics of pyeonyuk; however, the appropriate addition level of TP in pyeonyuk has not been established. To address this, an experiment was designed with one control and three TP treatments: control (TP 0%), T1: (TP 0.1%), T2: (TP 0.3%), and T3: (TP 0.5%). All the TP treatments markedly increased protein and ash contents compared to the control. The water holding capacity was equally retained with the control and T3 treatments, but was significantly lower with the T1 and T2 treatments in pyeonyuk ($p<0.05$). Lightness and redness values were both reduced with the addition of TP, whereas the yellowness value increased. Values for 2-thiobarbituric acid reactive substances and the total microbial count for pyeonyuk with added TP showed an improvement over time. As a result, the addition of TP did not have a significant negative influence on the quality characteristics of the pyeonyuk with addition of 0.5% TP being particularly effective for water retention capacity and inhibition of lipid oxidation.

Keywords pyeonyuk, dietary fibers, quality characteristics, turmeric powder, curcumin

Introduction

Global meat consumption has increased gradually in recent years, with an accompanied increase in the quantity of edible meat by-products generated daily in slaughterhouses; however, human consumption of these by-products has declined (Ockerman and Basu, 2004). Pork by-products include blood, bone, skin, feet, tail, red internal organs (liver, lung, heart, and kidney), white internal organs (large and small intestine), and head, that can provide energy, proteins, minerals, and vitamins necessary for human health (Kang et al., 2014; Seong et al., 2014). Consequently, pork by-products may be used as food resources. Pork head meat contains 21% tongue and 79% boneless meat (Gonulalan et al., 2004; Park, 2004), consisting of 57.0% moisture, 20% protein, and 21.5% fat, as well as a high level of essential amino acids like lysine, leucine, isoleucine, threonine, and phenylalanine (Ryu and Kim, 1984; Skarpeid et al., 2001). However, since demand for head meat has decreased, new ways of utilizing head meat through various processing methods must be found (Kim et al., 1999).

Curcumin, a natural phenolic yellow pigment obtained from the rhizomes of the turmeric plant (*Curcuma longa* L.), is a major component of turmeric and is commonly used as a spice and food-coloring agent (Govindarajan, 1980). Interestingly, turmeric was originally consumed as a food additive in curries to enhance aroma, storage conditions, palatability, and preservation (Jayaprakasha et al., 2005). The addition of turmeric to food preparations preserves freshness and imparts a distinctive flavor. Additionally, turmeric also has antioxidant properties due to the presence of phenolic compounds like curcumin (Govindarajan, 1980). Curcumin has been shown to elicit several biological effects, exhibiting anti-inflammatory, antioxidant, and hypolipidemic activity. Moreover, curcumin has also been studied intensively as a chemopreventive agent for multiple cancers, and has been suggested to contribute to the lower colorectal cancer rates observed in several Asian countries (Chainani-Wu, 2003; Sharma et al., 2005).

Postmortem lipid oxidation has been shown to decrease meat quality by degrading flavor, color, and order (Luciano et al., 2009; Morrissey et al., 1998). Oxygen free radicals initiate lipid peroxidation by generating hydroxyl radicals and superoxide anions. Therefore, lipid oxidation should be tightly regulated to maintain higher meat quality. Although the use of synthetic forms of antioxidants is widely accepted in the meat industry (Coronado et al., 2002), consumers prefer not to purchase meat products treated with non-natural forms of antioxidants for safety reasons (MCBride et al., 2007). To mitigate these recent concerns raised by meat consumers, the meat industry has begun to focus on the use of natural forms of antioxidants. Antioxidants may either be applied to meat-producing animals by feed supplementation (Descalzo et al., 2008) or by treatment during meat processing after slaughter (Akarpat et al., 2008; Estevez et al., 2005). In this study, we investigated the effects of turmeric powder (TP), a potent antioxidant, on pyeonyuk quality and storage characteristics, as well as the appropriate level of TP inclusion.

Materials and Methods

Formulation and processing procedure

The experimental design and the three pyeonyuk formulations used are provided in Table 1. Vacuum-packed pork head meat and pork sirloin were purchased from a local market (Open market Co., Jeonnam, Korea). The pork was trimmed of visible fat and fascia. Four liters of distilled water and 1 kg of head meat and sirloin were placed in an electronic pressure

Table 1. Formulations of pyeonyuk with turmeric powder (TP, %)

Items	CON	T1	T2	T3
Head meat	89.55	89.55	89.55	89.55
Sirloin	9.95	9.95	9.95	9.95
Salt	0.4	0.4	0.4	0.4
Pepper	0.1	0.1	0.1	0.1
Turmeric	0	0.1	0.3	0.5
Total	100.0	100.1	100.3	100.5

[*] Salt, pepper and turmeric were added as percentage unit for sum of major ingredients.

extractor, and cooked at 80℃ for 8 h. Pork head meat and pork sirloin were kept frozen at −24℃ for 1 d and then ground using a Model C50 silent cutter (FATOSA, Barcelona, Spain). After removing the skin, the turmeric was ground with a blender and prepared in powder form. Turmeric (Foodmam Co., Korea) was added according to the level of addition (0%, 0.1%, 0.3%, and 0.5%) along with other ingredients (salt, pepper), and then mixed at high speed (816 rcf). To complete the pyeonyuk, 1 kg of mixed meat was placed in a cube and stored at 4℃ for 12 h. Three replications were made for each treatment.

Analysis of curcumin content by HPLC

Curcumin was detected with separation and quantification by high-performance liquid chromatography (HPLC; isocratic), using an ultraviolet detector at a wavelength of 461 nm with a fixed flow rate (0.8 mL/min). 50 μL sample was injected onto the HPLC system (Varian, Walnut Creek, CA with Star 6.30 Chromatography Software). Chromatographic separation was achieved using a reverse-phase column (Waters Symmetry Shield™ 3.9×150 mm, 5-μm C18 column; Waters, Milford, MA) coupled to a guard column (Alltech® Absorbosphere™ 30×4.6 mm C18; Alltech Associates, Deerfield, IL). The quantitation of curcumin was by peak area based on a robust standard curve in a methanol matrix generated using a pure external standard. Linearity of the standard curve was verified with a single analysis of six different standard concentrations, performed in triplicate.

Proximate composition

Moisture, fat, protein, and ash contents in Pyeonyuk were assessed according to a well-established method (AOAC 2012; Chung et al., 2018).

Meat color

Pyeonyuk color was assessed by the previously described method (Piao et al., 2004) to determine L* (lightness), a* (redness), and b* (yellowness) from the surface of freshly cut pyeonyuk with 20 min bloom time. Each measurement was executed with 6 replicates and the average value was reported.

pH

To acquire pH data, 10 g from each pyeonyuk sample was homogenized in 100 mL distilled water for 30 s at 5,468 rcf and homogenized (Nihonseiki, Tokyo, Japan). The pH values of the homogenates were recorded using a calibrated pH meter (Mettler-Toledo Ltd, Leicester, UK) at 24 h and 14 d after slaughter.

Water holding capacity (WHC)

WHC was measured using a well-established in-house method (Chung et al., 2018; Laakkonen et al., 1970).

Cooking loss (%) and Texture profile analysis (TPA)

Emulsion-type pork pyeonyuk (a 3-cm-thick slice weighing 95–105 g) from each group was transferred into a polypropylene bag, cooked in a water bath at 70℃ for 40 min, and cooled to ambient temperature for 30 min. Cooking loss (%) was determined by the following equation; [(initial weight of pyeonyuk sample−the weight of pyeonyuk after cooking)/initial weight of pyeonyuk sample]×100.

For TPA analysis, previously prepared pyeonyuk was cut into multiple pieces [1 (width)×1 (length)×1 (height) cm] for a double compression cycle test. The TPA was performed using a rheometer (Sun Scientific Co., Tokyo, Japan with Rheology data systems version 3.0 for Windows) under constant table speed (60 mm/min) and 4 kg maximum load cell capacity.

Sensory evaluation

Well-trained in-house tasting panelists (n=5) participated in the sensory evaluation of fresh and cooked meat. Subjective color, marbling, hardness, juiciness, tenderness, flavor, and overall acceptability were scored using a 5-point hedonic scale, from 1– very pale, very low in intramuscular fat, very flabby, very dry, very tough, very mild, very unacceptable; to 5–very dark, very high in intramuscular fat, very firm, very juicy, very soft, very intense, very acceptable. The samples were independently evaluated at 3 different times by the panelists.

Volatile basic nitrogen (VBN) and 2-thiobarbituric acid reactive substances (TBARS)

The VBN (Choi et al., 2017; Short, 1954) and TBARS values were measured using a method of Choi et al. (2017).

Microbiological analysis

Ten grams of fermented pyeonyuk (10 g) was aseptically retrieved from each treatment, transferred to sterile plastic bags, and homogenized with 90 mL of a 0.1% peptone solution in a Stomacher 400 Lab Blender (Seward Ltd, West Sussex, UK) for 90 s. Homogenates were diluted 10 times using 1 mL in fluid agar and inoculated on TMC medium. Inoculated samples were incubated at 37℃ for 48 h according to a previously described method (APHA, 1992). Lactic acid-producing bacteria (LAB) were inoculated on de Man, Rogosa, and Sharpe agar and subsequently cultured at 37℃ for 48 h. Results are expressed as the colony forming units with log transformation (CFU)/g.

Statistical analysis

The data were tested by analysis of variance using the SAS program (2012) and the trends were analyzed using Duncan's multiple range test.

Results

Curcumin content of turmeric by HPLC analysis

The curcumin content of TP obtained by HPLC analysis is shown in Table 2. The curcumin content of TP used in this experiment was similar to Jaggi (2012), who reported a curcumin content of 6.3–7.0 mg for the root and rhizome of turmeric, as well as Kim (2002), who recorded a value of 3–5.43 mg for curcumin content when analyzing the maintenance of curcumin stability.

Table 2. Curcumin content by high-performance liquid chromatography (HPLC) analysis (mg/g)

Composition	Content
Curcumin	5.07±0.12 (mg/100 g)

Proximate analysis

The results of the proximate analysis of the pyeonyuk according to the addition level of TP are shown in Table 3. The moisture content of the pyeonyuk samples with added TP was 64.17–65.78%. The water content decreased proportionally with increasing TP content, since the water content in TP was lower than in the pyeonyuk; therefore, water content is influenced by the amount of TP added. Increased addition of whey powder has been reported to reduce the water content in beef meatballs (Serdaroglu, 2006). The protein content of the pyeonyuk samples was significantly lower in the control than in the TP treatments. According to a previous study, the protein content of turmeric was 2.85% (Lim et al., 2011). The fat content of the pyeonyuk samples did not change significantly with addition of TP. The ash content of the control and all the treatments ranged from 0.40 to 0.73, and was higher in pyeonyuk with added TP than in the control. The addition of powder, like fruit skins, has previously been reported to increase the ash content of meat products (Serdaroglu, 2006), like that observed in our samples. The pH of all the treatments with added TP ranged from 6.34 to 6.36, lower than the control. The pH of the TP was 6.02, suggesting that the pH was lowered with the addition of TP (Choi et al., 2011).

Quality characteristics

The quality characteristics of the pyeonyuk according to the addition level of TP are presented in Table 4. Lightness (L*), redness (a*), and yellowness (b*) values were determined for the pyeonyuk. The L* values of the samples ranged from 67.16 to 71.23, and tended to decrease with increasing addition of TP. The pyeonyuk control samples showed the highest lightness value among the treatments. These results are like those recorded for chicken sausage prepared with between 1% and 4% TP (Yoon and Choi, 2011), as well as for mandupi with addition of between 1% and 7% curcuma powder (Ann, 2011). The a* redness values were significantly higher in the control than with the TP treatments, which all exhibited negative redness values. The control group presented the lowest yellowness value (b*) at 14.84, while the yellowness value for the TP treatment group showed a tendency to increase, being in the range of 33.35 to 52.05. One of the components of turmeric is curcumin, a phenolic yellow spice extracted from the roots of *Curcuma longa* L. (Zingiberaceae). The curcumin content of turmeric is 6.29 mg/g (Yoon and Choi, 2011), and the increased yellowness observed in our samples was due to the dense and brown colors of turmeric used in this study. Moreover, Lim (2011) also showed that the addition of 2%, 4%, 6%, and 8% turmeric to bread resulted in reduced brightness and redness, and increased yellowness. Adding TP decreased the brightness and redness, and the results of this study suggest that the constituents of TP influenced meat color. The WHC of pyeonyuk was in the range of 51.52–73.95. No significant difference in WHC was observed between the control and T3 treatment, while the T2 treatment elicited the lowest WHC value. If the pH is low, meat color is pale, the WHC is reduced, and the

Table 3. Proximate analysis of the pyeonyuk according to the addition level of turmeric powder (TP)

Item	CON	T1	T2	T3
Moisture (%)	67.48±0.98[a]	65.78±1.61[b]	64.53±3.36[c]	64.17±0.38[c]
Protein (%)	14.71±1.19[b]	18.44±0.82[a]	18.84±3.98[a]	18.50±0.80[a]
Fat (%)	16.91±0.40[a]	13.99±0.43[b]	15.97±1.08[a]	16.62±0.53[a]
Ash (%)	0.40±0.02[c]	0.73±0.04[a]	0.63±0.00[b]	0.69±0.03[a]
pH	6.47±0.01[a]	6.34±0.01[b]	6.36±0.01[b]	6.36±0.00[b]

[a–c] Mean±SD with different superscript letters indicate significant differences ($p<0.05$).
CON, control (no addition); T1, turmeric 0.1%; T2, turmeric 0.3%; T3, turmeric 0.5%.

Table 4. Quality characteristic of the pyeonyuk according to the addition level of turmeric powder (TP)

Item		CON	T1	T2	T3
Hunter color	L*	71.23±4.39^{a}	69.91±1.39^{b}	68.93±1.22^{c}	67.16±2.38^{d}
	a*	1.12±0.60^{a}	–1.99±0.77^{b}	–3.82±0.16^{c}	–3.58±0.22^{c}
	b*	14.84±0.70^{d}	33.35±1.23^{c}	46.69±1.34^{b}	52.05±1.20^{a}
WHC (%)		72.56±29.54^{a}	61.73±12.29^{b}	51.52±4.02^{c}	73.95±7.65^{a}
Cooking loss (%)		46.72±7.99	42.30±17.06	46.72±7.99	47.40±3.41
Springness (%)		40.71±11.23	54.61±10.82	45.51±16.88	42.31±9.40
Cohesiveness (%)		22.88±4.97	35.18±15.23	23.01±4.25	23.59±9.49
Chewiness (g)		77.43±43.81^{c}	179.42±40.75^{a}	145.87±41.58^{ab}	99.97±42.27^{bc}
Hardness (g)		1,860.27±1,228.63^{c}	9,105.73±2,682.18^{a}	6,816.45±3,431.07^{ab}	4,028.23±2,218.97^{bc}

$^{a–d}$ Mean±SD with different superscript letters indicate significant differences ($p<0.05$).
CON, control (no addition); T1, turmeric 0.1%; T2, turmeric 0.3%; T3, turmeric 0.5%, WHC, water holding capacity.

texture becomes poor. In contrast, when the pH is high, a large amount of salt-soluble protein is extracted when salt is added, thereby increasing the emulsifying and binding properties (Choi et al., 2006). This implies that the WHC of the pyeonyuk samples with added TP was lower than the control. There was no significant difference between treatments in cooking loss, springiness, or cohesiveness. Chewiness and hardness were significantly higher with the T1 compared to the other treatments, and significantly lower in the control treatment compared to all the TP treatments. In addition, chewiness and hardness tended to decrease with increasing addition of TP. According to a study on the quality characteristics of jeung-pyun not made with parched tea leaf powder (Kim and Hong, 2011), adding 1% of tea leaf powder produces the lowest hardness, while Yoon and Choi (2011) showed that hardness and chewiness tended to increase with increasing inclusion levels of TP (2%, 3%, and 4%).

Sensory test

The results of the sensory evaluation of the pyeonyuk according to the addition level of TP are shown in Table 5. Regarding texture, there was no significant difference between the T1 treatment and the control, but the T2 and T3 treatments were both significantly higher than the control. For the pyeonyuk color, the T3 treatment showed the highest score, with values of 4.10±0.89, due to the stronger color resulting from increased addition of TP. Shin and Joung (2018) previously reported that the color increased with increasing amounts of up to 1% of added TP, and similar results were obtained in this study. The juiciness of pyeonyuk showed significantly higher values in the control, T1, and T2 treatment groups than in T3, but not significantly different in the T2 and T3 treatments. There was no statistically significant difference among treatments in flavor and total acceptability of the pyeonyuk. According to a study by Cho et al. (2006), less than 1% of turmeric extract should be added to sausages for the best sensory results. In this study, the addition of 0.5% TP to pyeonyuk elicited an acceptable sensory evaluation.

Storage characteristics

The storage characteristics of the pyeonyuk according to the addition level of TP are shown in Table 6. The TBARS value for T1 was significantly higher than for the other treatments at day 0, with the T2 treatment presenting the lowest value. After 3 and 7 days of storage, the TBARS value was highest for the control compared to the other treatments. Jung et al. (2004) suggested that curcumin and fragrance components, which have phenol groups, are closely related to antioxidant activity. In

Table 5. Sensory evaluation of the pyeonyuk according to the addition level of turmeric powder (TP)

Items	CON	T1	T2	T3
Texture	2.60±0.54[b]	2.60±0.54[b]	3.20±0.83[a]	3.40±0.54[a]
Color	2.60±0.44[c]	2.60±0.54[c]	3.60±0.54[b]	4.10±0.89[a]
Juiciness	3.20±0.54[a]	3.20±0.44[a]	2.60±0.54[ab]	2.40±0.54[b]
Flavor	3.20±0.54	3.20±0.44	3.40±0.89	3.20±0.83
Total acceptability	3.00±0.54	3.10±0.54	3.10±0.74	3.00±0.93

[a–c] Mean±SD with different superscript letters indicate significant differences ($p<0.05$).
CON, control (no addition); T1, turmeric 0.1%; T2, turmeric 0.3%; T3, turmeric 0.5%.

Table 6. Storage characteristics of the pyeonyuk according to the addition level of turmeric powder (TP)

Item	Storage	CON	T1	T2	T3
TBA (mg malonaldehyde/1,000 g)	0 day	0.88±0.01[b]	0.97±0.03[a]	0.84±0.01[c]	0.88±0.01[b]
	3 day	1.18±0.01[a]	0.85±0.05[b]	0.46±0.01[c]	0.48±0.00[c]
	7 day	1.13±0.01[a]	0.82±0.01[b]	0.79±0.03[b]	0.72±0.04[c]
VBN (mg%)	0 day	14.04±0.31[c]	16.10±0.15[a]	15.09±0.27[b]	15.28±0.31[b]
	3 day	17.66±0.41[a]	17.20±0.15[a]	15.37±0.27[b]	15.55±0.41[b]
	7 day	17.75±0.15[b]	17.84±0.54[b]	16.28±0.31[c]	19.21±0.27[a]
TMC (CFU/g)	0 day	3.44±0.06[a]	2.80±0.28[ab]	2.36±0.02[b]	2.70±0.57[ab]
	3 day	4.55±0.09[b]	5.34±0.01[a]	5.32±0.03[a]	5.32±0.09[a]
	7 day	6.83±0.12[a]	4.99±0.12[b]	5.01±0.08[b]	5.17±0.08[b]

[a–c] Mean±SD with different superscript letters indicate significant differences ($p<0.05$).
CON, control (no addition); T1, turmeric 0.1%; T2, turmeric 0.3%; T3, turmeric 0.5%, TBA, thiobarbituric acid; VBN, volatile basic nitrogen; TMC, total microbial counts.

this study, the observed antioxidative activity of curcumin, a physiologically active substance found in turmeric, is thought to account for the antioxidative properties of pyeonyuk, consistent with the suppression of oxidation observed in pork sausage with the addition of licorice and turmeric (Cho et al., 2006). The value for VBN was higher than the control at initial (day 0) storage. The VBN values for the control and T1 were significantly higher compared to the other treatments at day 3 of storage. However, after 7 days of storage, the VBN value for the T3 treatment was significantly higher than for the other treatments, with the control and T1 treatments exhibiting similar VBN values. According to Korea Food Law (2002), the allowable VBN content is limited to 20 mg VBN/100 g or less, with 5% to 10% being considered fresh. The VBN content tended to increase with extended treatment for all groups, but the control group showed the lowest VBN content at initial storage. This suggests that addition of 0.1% and 0.3% TP to pyeonyuk may delay protein degradation until day 7, consistent with the observed reduction in the VBN content in sausage with added green tea powder (Choi et al., 2003). Total microbial counts (TMC) showed the highest values at day 0 and day 7 of storage compared to the other treatments; however, at day 3, the control presented the lowest TMC compared to the other treatments. All treatments showed TMC levels within 6.83 Log CFU/g after 7 d. According to Korea Food Law (2002), total microbial counts increase with increasing storage periods. In food, the concentration of general bacteria necessary to ensure sanitary safety is approximately 1×10^5 CFU/g; however, this figure was lower with TP treatment during the storage period. This indicates that the addition of TP to pyeonyuk resulted in a relatively small number of viable cells because microbial growth was suppressed by the antifungal activity of turmeric, thus maintaining storage stability. These results are consistent with those of a study on the improvement of storage properties and quality in the traditional seasoning beet containing medicinal herb extracts; they are also identical to the reported improved storage properties (Park et al., 2005) and reduction in sodium nitrate by *Glycyrrhiza uralens*is and *Curcuma longa* in pork sausages (Cho et al., 2006).

Discussion

This study was conducted to investigate the effects of TP on pyeonyuk quality and storage characteristics, as well as the appropriate level of TP inclusion. In conclusion, TP is a natural food additive with the potential to increase the oxidant stability of pyeonyuk without diminishing its quality. The storage characteristics of pyeonyuk with added TP improved over time. Treatment with 0.5% TP did not decrease the WHC compared to the control, and increased the storage characteristics by inhibiting lipid oxidation. Therefore, 0.5% TP can be applied as a natural preservative for pyeonyuk, as well as a functional food. These results are directly applicable to the meat industry due to the resultant improved food storage and nutritional quality. Antioxidants have a crucial role in preventing lipid peroxidation during food storage. TP is relatively safer than artificially synthesized antioxidants; consequently, potential consumers may select meat products containing TP. Although TP also has other health promoting effects, some people prefer not to consume TP due either to the unpleasant odor or acceptability. Based on our results, a small amount of TP added to pyeonyuk was acceptable, and if people were to consume pyeonyuk with added TP, then absorbed TP would elicit multiple health-promoting effects.

Furthermore, in a future study, we may consider supplementing TP in pig feed to improve meat quality. There is cumulative evidence that dietary antioxidants are available for absorption and distribution to the peripheral tissues of animals (Akarpat et al., 2008; Descalzo et al., 2008). Our present data and another report (Estevez et al., 2005) clearly demonstrated that the presence of natural forms of antioxidants in processed meat resulted in multiple beneficial effects. Other antioxidants like vitamin C and E may improve meat quality by suppressing lipid peroxidation; however, to our surprise, curcuma has been suggested to possess stronger antioxidant effects than vitamin C and E (Miquel et al., 2002). The addition of TP in feed may be more beneficial than utilizing TP as an additive. Feeding can deliver TP to the most peripheral tissues, promoting health properties like feeding efficiency and regulation of hematological parameters (i.e., lipid profiles and immune cells). If the TP feeding method is successful in the future, this may result in functional meat with a higher added value.

Conflicts of Interest

No conflicts of interest, financial or otherwise, are declared by the authors.

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Author’s Contributions

Conceptualization: Choi YI, Ha J-H. Data curation: Bae IK, Kim KJ, Ha J-H. Editing: Bae IK, Kim KJ, Choi JS, Choi YI, Ha J-H. Software: Bae IK, Kim KJ. Investigation: Choi JS, Choi YI, Ha J-H. Writing - original draft: Bae IK, Choi YI, Ha J-H. Writing - review & editing: Bae IK, Kim KJ, Choi JS, Choi YI, Ha J-H.

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