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EFFECT OF GAC FRUIT POWDER ON QUALITY AND NITROSATION ACTIVITY OF MEAT PRODUCT

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ABSTRACT

Nitrite is important for meat product quality especially for color stabilization. However, toxicity of nitrite according to nitrosation reaction raises interest of many researchers. To improve the quality and safety of meat product, nitrite was substituted with freeze dried gac fruit aril (GP). Frankfurters were produced with the combination of 50-150 mg/kg sodium nitrite and 0-4% GP and stored at 4°C. Color, pH and lipid oxidation (thiobarbituric acid reactive substances, TBARS) were determined weekly for 4 weeks whereas sensorial qualities were evaluated after cold storage at 4°C for one day. Aqueous determination of N-nitrosodimethylamine (NDMA) content was carried out by high-performance liquid chromatography (HPLC) at day zero before and after a two-step *in vitro* digestion. The results showed that replacement of nitrite with GP caused slightly increase in pH of frankfurter in a concentration dependent manner and falling of pH values were observed after 21 days storage. TBARS values also elevated but only when the highest level of GP (4%) was employed and storage time reached 28 days. Moreover, GP resulted in declining of L* (lightness) and greater of a* (redness) and b* (yellowness) values of frankfurter which these were paralleled with increasing of color acceptability score evaluated by panelists. These color values were unchanged throughout storage period at 4% GP content. Finally, NDMA only occurred after *in vitro* digestion and tended to increase in the presence of GP. It can be concluded that GP successfully improved color stability and acceptability of frankfurter. However, over dose of GP incorporation (4%) led to increasing of lipid oxidation and nitrosation reaction.

Keywords: Gac, *In vitro* digestion, Nitrosamine, Meat products, Lipid oxidation, TBARS

INTRODUCTION

Momordica Cochinchinensis Spreng is commonly known as gac. It is originated in Southeast Asia and most typical in Myanmar, Thailand, Laos, Bangladesh, Malaysia, Philippines, and Vietnam. All parts of the plant have attracted interest of researchers in recent years and are used for medicinal and nutritional purposes. The young fruit is rich in vitamin C, calcium, and fiber whereas gac aril of fully mature fruit contains superior amount of lycopene, flavonoid, and phenolic compounds and, therefore, high in antioxidant activities (West and Poortvliet, 1993). Being reported as a rich source of lycopene, compared to many fruits and vegetables especially tomato (Kubola and Siriamornpun, 2011), gac aril has intense red color which makes it a promising natural food colorant. Gac oil powder could be successfully incorporated into food products such as yogurt, pasteurized milk and cake to improve color retention, β -carotene and lycopene content (Kha *et al.*, 2015). Moreover, lycopene is a potent antioxidant and plays an important role in prevention of many diseases such as cancer, cardiovascular diseases as well as modulation of immune system (Aust *et al.*, 2003).

The reaction of nitrite with pigment in meat forms stable red color which is essential to consumer likeliness. The European Food Safety Authority (EFSA) stated that addition of nitrite is necessary to inhibit pathogenic microorganisms in particular *Clostridium botulinum* and the maximum level is 150 mg/kg (FAO/WHO, 1996). However, nitrite or nitrogen oxides can react with secondary amines in meat to form nitrosamine, the reaction of which is known as nitrosation. A multistep process of nitrosation includes nitrous acid (HNO₂) production by the addition of a hydrogen ion to the nitrite ion in acidic condition of gastric cavity following with water molecules removed to form an ultimate toxicant, nitrosonium ion (N=O⁺). Nitrosamine has shown toxicological significance in human by formation of DNA adducts and its carcinogenic effect has been well established. Ohshima and Bartsch (Ohshima and Bartsch, 1999) demonstrated that suitable condition of nitrosation rather involved with many factors including pH, amine substrate and nitrosating agent. Color is an important factor for the customer acceptance in meat-based food, therefore, many researchers have studied the stability of color of fresh and processed meat and optimized the use of nitrite in order to maintain good color and enhance product safety (Feiner, 2009). Inhibition of nitrosation has been reported; the addition of

nitrosation inhibitor such as ascorbic acid, isothiocyanate and tocopherols to the curing mixture has resulted in significant reduction in the levels of nitrosamine (Biaudet *et al.*, 1996). Meat products contain high lipid content that makes it prone to lipid oxidation. Not only primary cause of flavour changes, lipid oxidation is considered as an important factor for color and nutritive value alteration in meat products as well as generation of toxic and carcinogenic compounds (Jensen *et al.*, 1998). Control of oxidation in meat product has become increasingly important to prevent quality deterioration especially during chilling storage of processed meat.

Therefore, this study was aimed to evaluate the possibility of gac aril powder application as a natural colorant in meat products and its effects on product quality. Moreover, degree of nitrite substitution on nitrosamine content in meat products before and after enzymatic *in vitro* digestion was also determined.

MATERIAL AND METHODS

Chemicals and reagents

Pancreatin, pepsin, N-nitrosodimethylamine, trichloroacetic acid (99%), 1,1,3,3-tetramethoxypropane (99%), 2-Thiobarbituric acid (98%), HPLC grade methanol and acetonitrile were obtained from Sigma-Aldrich (Singapore). HPLC grade water was acquired from Milli-Q water purification system (Millipore, Bedford, USA.).

Freeze dried gac fruit aril preparation

Fully mature gac fruits were purchased from local farm in Chiang Rai, Thailand. Gac arils were removed from the seeds and milled in a blender to obtain homogenous aril. The aril paste was freshly frozen at -40 °C. Then under freeze-drying system at 10⁻² Pa, the frozen aril was dried overnight to obtain pure gac aril powder. The powder was blended and sieved to achieve homogenous fine powder. Gac fruit powder (GP) was stored in a cool dry place for further utilization.

Frankfurter preparation

Production of frankfurters was carried out according to Laemthong Food Products Co. Ltd. procedure. The frankfurters were divided into 9 treatments with different levels of nitrite (50, 100, and 150 mg/kg) and freeze dried gac fruit aril (0, 2, and 4 g/100 g). Briefly, lean pork (80 % w/w) and pork fat (20 % w/w) purchased from local market were chilled and finely chopped in a bowl chopper at the holding temperature below 5°C prior to all ingredients were added including nitrite and GP. Liquid smoke at 75 °C for 30 min was employed after casing in a 10 cm long with 3 cm diameter following with cooking in 100 °C water bath until internal temperature reached 80 °C. Cooked frankfurters were instantaneously cooled down in ice-cold water and vacuum packed. Samples were stored at 4 °C and taken at day 0, 7, 14, 21, and 28 for physicochemical analysis. Sensory evaluation was performed at one day after storage.

Color measurement

Determination of color was carried out as described previously (Eyiler and Oztan, 2011). Redness (a*), yellowness (b*), and lightness (L*) of inner cuts of samples were achieved by using Hunter Lab Color Quest XE (Hunter Associates Laboratory, Inc., USA.).

pH measurement

A 10-g of sample was homogenized at 5,000 rpm with 50 mL of distilled water. The homogenate was filtered through a filter paper and then pH of sample was assessed by using Digital pH-meter.

Determination of thiobarbituric acid reactive substances (TBARS)

TBARS assay was slightly modified as described previously (Meineri et al., 2013). Samples (10 g) were homogenized with 10% trichloroacetic acid (20 mL). The homogenate was centrifuged at 600 rpm for 5 min at controlled temperature of 4 °C. The supernatant was subsequently filtered through Whatman No.1 filter paper. To 1 mL of filtrate, 1 mL of a 0.02 M 2-thiobarbituric acid solution (TBA) was added prior to heating up in boiling water for 20 min. The pink color of sample was developed according to the reaction of TBA and oxidation products and was spectrophotometric measured at 538 nm. The content of malondialdehyde (MDA) was expressed as mg MDA/kg calculated using calibration curve of 1,1,3,3-tetramethoxypropane standard.

In vitro digestion

The method for *in vitro* digestion was modified from Boisen and Fernández (1997). The two steps digestion mimicking the protein digestion processes in the stomach and small intestine was carried out. Firstly, 0.1 M of pH 6.0 phosphate buffer was added into the flask containing ground sample (0.5 g). The mixture was continuously mixed using magnetic stirrer. A-10 mL HCl (0.2 M) was added prior to the pH adjusted to 2.0. The combination was digested for 2 h at 39 °C with pepsin (25 mg/mL) in the presence of 0.5 mL of 0.5% chloramphenicol in ethanol. Subsequently, 10 mL of 0.2 M phosphate buffer (pH 6.8) and 5 mL of 0.6 M NaOH solution were incorporated and pH was adjusted to 6.8. Finally, pancreatin (100 mg/mL) was added and left for 4 h at the same temperature. The complete digestion samples were further subjected to N-nitrosodimethylamine analysis.

Determination of N-nitrosodimethylamine

N-nitrosodimethylamine (NDMA) in samples was analyzed by HPLC (HPLC Waters Alliance 2695 with PDA and ELSD) equipped with reverse phase C18 column (150 mm x 3.9 mm, 5 µm particle size) according to Krauss and Hollender (2008) with some changes. A gradient mobile phase was adopted where ratio of 0.1 mM ammonium acetate/methanol at 85/15 was increased to 0/100 in 18 min. Injection volume of sample was 20 µL and mobile phase flow rate was 100 µL/min. Standard curve was produced employing NDMA standard solutions at a concentration range of 0-10 mg NDMA/kg.

Sensory evaluation

Sensory evaluation was carried out on day 1 of refrigerated storage using the 9-point Hedonic Scale with 20 panelists. Frankfurters were heated by steaming and halved before serving with 3 digit random numbers. Four attributes i.e. color, texture, odor, and taste were evaluated in the numerological scale, 1 and 9 referred to dislike extremely and like extremely, respectively. Overall acceptability served as indication of preference by the panel, but it was not used to infer consumer acceptance.

Statistical analysis

Three replicates were used in the experiment. Factorial design was employed and analysis of various (ANOVA) of the obtaining data were analyzed where factors that significantly different between means were determined using Duncan's new multiple range test. Differences were considered significant at the $p < 0.05$ level.

RESULTS AND DISCUSSION

Effects of nitrite and GP on pH and color

Table 1 shows the effect of nitrite and GP on pH of frankfurter during storage period (0, 7, 14, 21, and 28 days). The results illustrated that nitrite alone led to similar pH values of frankfurter at day 0 being 6.28, 6.09 and 6.23 at 50, 100 and 150 ppm of nitrite, respectively. These results are in agreement with previous report by Deda and colleagues (Deda et al., 2007). However, considering increasing the level of GP, it can be seen that pH value increased in concentration dependent manner with increasing levels of GP, especially when 100 and 150 ppm nitrite were combined with GP. This is thought to be a result of high pH of gac aril powder. The pH values of samples were quite stable during day 0 to day 14 but markedly decreased after two weeks (Table 1). Chilling storage at 4 °C is designed to maintain microbiological quality of processed meat where the shelf life of which is generally up to 14 days. Spoilage microorganisms, especially lactic acid producing bacteria, grow slowly and falling of pH observed after this period. Among different nitrite levels, 150 ppm maintained pH at higher level compared to 50 and 100 ppm after 21-day storage. Similarly, it was previously reported that sodium nitrite could inhibit growth of lactic acid bacteria isolated from vacuum-packed cooked ring sausages, the effect was very limited at 50 and 100 ppm but strong inhibition was observed at the dose as high as 400 ppm (Korkeala et al., 1992). GP showed little effect on pH values. Inhibition of pH changes were obtained when nitrite was added at high level.

Color L*, a*, and b* values of samples were affected by both nitrite and GP content (Table 2). At high concentration of nitrite, lightness (L*) increased whereas that was reduced in the presence of higher GP level. The a* (redness) and b* (yellowness) values, on the other hand, increased significantly with increasing GP content. These results indicate that the color of meat product is more red-yellow in the presence of GP. This was not surprising because GP is a rich source of lycopene compared to other natural sources, 70 times more than tomato (Ishida et al., 2003). Tonucci and colleagues reported, in the tomato pulp powder, that lycopene is the predominant carotenoid responsible for the red color of the powder and its derived products (Tonucci et al., 1995). However, the added GP increased b* value which inferred that the products was more likely in orange color. The orange color developed is possibly a result of reaction between fat and lycopene which may turn lycopene from a reddish color into yellow as also reported by Hayes et al. (2013). Moreover, following 28-day storage there were obvious changes of lightness (L*), redness (a*) and yellowness (b*) of frankfurter in the samples containing low levels of GP (0 and 2%) whereas no color change was recorded in 4% GP incorporated samples. This infers that GP improved color stability of frankfurter throughout the shelf life of product. Though natural colorant is readily for degradation, lycopene is lipid soluble pigment that considerably highly stable. It is well established that the most important factors in food processing that cause degradation of lycopene are heat, light and oxygen (Shi et al., 1999). During storage of frankfurter, destruction of lycopene was retarded because oxygen was excluded under vacuum packaging and temperature was well controlled at 4 °C.

Effects of nitrite and GP on lipid oxidation

Addition of nitrite at low levels did not affect lipid oxidation of frankfurter as indicated by TBARS values ($p > 0.05$) (Table 3). Lin and colleagues (Lin et al., 2011) reported, in different meat product, that nitrite led to a significant reduction of TBARS values. Study in Italian sausage, de Oliveira et al. (2011) found that without antioxidant incorporated, TBARS values of samples decreased when 100 mg/kg nitrite was added. However, at 200 mg/kg nitrite, adverse effect was noted especially when nitrite was combined with antioxidant. It was suggested that the antagonistic effect observed was due to an interaction between nitrite and chemical compounds present in natural antioxidant derived from plant extract. Similarly, addition of GP tended to increase the TBARS values at the highest level studied (Table 3). The negative effects of GP on lipid oxidation are also presumably attributed to high fatty acid content of gac aril in combination with polyunsaturated fatty acids in the muscle and tissues (Buckley et al., 1989). Chemical composition of gac aril has been well established. The gac fruit aril contains 22% fatty acid by weight which composes of 32% oleic, 29% palmitic, and 28% linoleic acids (Ishida et al., 2003). From the composition of gac aril, it can be said that high fatty acid may be one of the causes of oxidation. Moreover, significant amount of lycopene in gac fruit aril might also be the case since it has been reported that 20 µg/mL lycopene is a pro-oxidant of triglycerides (Haila et al., 1996). However, all treatments had TBARS value less than 2 mg MDA/kg up to 28 days of storage. According to Greene and Cumuze (1982), the minimum TBARS value which causes off-flavor in meat products is 2 mg MDA/kg.

Therefore, it is important to point out that GP, at the range of study, showed no major effect on lipid oxidation and as a result, no effect on sensory attribute was

observed. Moreover, the TBARS values were only slightly changed until 21 days of storage and a significant increase was detected at 28-days (p<0.05).

Table 1 Effect of nitrite and GP on pH of frankfurter products

Factors		pH				
Nitrite (ppm)	GP(g/100g)	0 d	7 d	14 d	21 d	28 d
50	0	6.28±0.13 ^{bcB}	6.47±0.02 ^{bA}	6.70±0.09 ^{aAB}	5.43±0.14 ^{bcC}	4.83±0.04 ^{bd}
	2	6.55±0.07 ^{aA}	6.21±0.01 ^{eB}	5.67±0.06 ^{dC}	5.28±0.09 ^{cD}	4.56±0.04 ^{eE}
	4	6.28±0.12 ^{bcA}	6.32±0.03 ^{dA}	6.15±0.04 ^{bB}	5.26±0.06 ^{cC}	4.71±0.02 ^{cdD}
100	0	6.09±0.14 ^{dA}	5.89±0.07 ^{fB}	5.48±0.01 ^{eC}	4.97±0.02 ^{dD}	4.23±0.05 ^{eE}
	2	6.30±0.02 ^{bcA}	6.35±0.06 ^{cdA}	6.02±0.01 ^{cB}	4.86±0.64 ^{dC}	4.58±0.05 ^{eD}
	4	6.41±0.11 ^{abcB}	6.67±0.04 ^{aA}	6.21±0.04 ^{bB}	5.45±0.23 ^{bcC}	4.93±0.02 ^{ad}
150	0	6.23±0.10 ^{dAB}	6.40±0.01 ^{bcA}	6.14±0.05 ^{bB}	5.74±0.23 ^{acC}	4.77±0.06 ^{bcD}
	2	6.30±0.010 ^{bcB}	6.47±0.04 ^{bA}	6.17±0.03 ^{bcC}	5.56±0.09 ^{abD}	4.42±0.06 ^{fE}
	4	6.43±0.01 ^{abA}	6.43±0.01 ^{bcA}	6.01±0.09 ^{cB}	5.62±0.25 ^{abcC}	4.66±0.03 ^{dD}

^{abc}Mean values in the same column bearing different superscripts are significantly different (p<0.05).

^{ABC}Mean values in the same row bearing different superscript are significantly different (p<0.05).

Effects of nitrite and GP on N-nitrosodimethylamine

Nitrite is converted to nitric oxide when antioxidant such as ascorbic or caffeic acid is incorporated hence formation of nitrosamine is limited. The findings in the current study demonstrated that NDMA was not detected before *in vitro* digestion application (Table 4) implying that formation of NDMA requires the acid condition of gastric as reported by Meineri and colleagues (Meineri *et al.*, 2013). However, prior to gastric digestion system, NDMA was generated. As expected, increasing level of nitrite led to elevation of NDMA content in samples (p< 0.05). Surprisingly, the addition of GP tended to increase NDMA value, however, without statistical significance (p>0.05). Similar results were reported by Biaudet *et al.* (1996). It was suggested that nitrogen oxide, a product from reduction of nitrite, can further react with unsaturated lipids and results in transnitrosation of secondary amine. Therefore, in a corporation with high fatty acid content of GP, nitrite enhanced NDMA formation. In addition, Combet *et al.* (2007) also reported the results of *in vitro* assay that ascorbic acid inhibited NDMA formation by 5 folds in aqueous solution. However, addition of 10% lipid converted ascorbic acid from inhibiting to promoting nitrosation. This may be explained by nitric oxide, formed by ascorbic acid, can regenerate nitrosating species by reacting with oxygen in the lipid phase. Moreover, it can be seen that increasing of nitrosamine content in the presence of antioxidant was concentration dependent (Table 4). Walter *et al.* (1976) reported that N-nitrosopyrrolidine (NPYR) in fried bacon was suppressed when ascorbate was

incorporated at a low concentration of 300 mg/kg while adverse effect was observed at the higher level. Obviously, high concentration of antioxidant leads to increasing production of nitric oxide and simultaneously promote the reaction with unsaturated lipids and as a result secondary amine reaction increased.

Sensory evaluations of frankfurter products

The results of sensory evaluation (Table 5) showed that nitrite and GP had a marked significant effect (p<0.05) on color of products whereas taste, texture and overall acceptance were slightly different and no effect on odor was observed. Addition of GP increased acceptability of color and texture but slightly lower the score of product taste (p<0.05). The results of greater color acceptability as affected by GP is inferring that the red-yellow color of frankfurters was preferable. However, the taste of the frankfurter, on the other hand, was lower when 4% GP was incorporated and the results indicated that taste of frankfurter affected overall acceptability the most, as can be seen from the highest and lowest overall acceptability were noted in the sample that had the highest and lowest taste score, respectively. The reason for lower taste score in the presence of GP was thought to be due to the unique flavor of gac aril which might interact with flavoring agents added into frankfurter according to standard recipe. However, this could be easily overcome by adjusting the content of herbs and spices.

Table 2 Effect of interaction between nitrite and GP on color parameters (L*, a* and b*) of frankfurter products

Factors		L*		a*		b*	
Nitrite (mg/kg)	GP(g/100g)	0 d	28 d	0 d	28 d	0 d	28 d
50	0	58.69±1.31 ^c	58.72±0.70 ^{ans}	6.53±0.24 ^e	4.87±0.88 ^{c*}	10.74±0.69 ^e	12.03±0.41 ^{c*}
	2	55.23±0.48 ^d	55.24±1.13 ^{bns}	19.58±0.61 ^b	17.59±0.47 ^{b*}	23.74±0.94 ^b	23.20±0.22 ^{bns}
	4	53.12±1.19 ^e	51.71±1.20 ^{cns}	23.04±0.75 ^a	22.87±1.72 ^{ans}	24.92±0.86 ^b	26.00±1.39 ^{ans}
100	0	63.05±1.05 ^b	60.86±1.04 ^{a*}	5.56±0.13 ^e	5.79±0.28 ^{c*}	10.93±0.46 ^e	11.91±0.36 ^{cns}
	2	56.23±0.73 ^d	55.20±1.73 ^{bns}	18.26±0.33 ^c	18.95±0.50 ^{bns}	22.33±1.17 ^c	23.40±0.91 ^{bns}
	4	52.99±0.70 ^e	53.78±2.07 ^{bcns}	23.71±0.83 ^a	22.03±2.02 ^{ans}	26.46±1.04 ^a	24.64±1.08 ^{abns}
150	0	65.79±1.03 ^a	60.61±0.32 ^{a*}	5.72±0.19 ^e	5.87±0.22 ^{cns}	8.25±0.08 ^f	10.68±0.41 ^{c*}
	2	58.74±1.19 ^c	54.08±1.22 ^{bc*}	12.99±0.53 ^d	17.19±1.54 ^{b*}	17.63±0.86 ^d	24.39±1.58 ^{qab*}
	4	54.94±0.65 ^d	53.30±2.43 ^{bcns}	22.88±0.91 ^a	22.26±3.08 ^{ans}	25.10±1.33 ^b	26.17±1.84 ^{ans}

^{abc}Mean values in the same column bearing different superscripts are significantly different (p<0.05).

*=Mean values are significant different between 0 and 28-day (p<0.05).

ns=non-significant difference between 0 and 28-day

Table 3 Effect of nitrite and GP on TBARS value (mg MDA/kg sample) in frankfurter products

Factors	TBARS (mg MDA/kg)						
	Nitrite (mg/kg)	GP(g/100g)	0 d	7 d	14 d	21 d	28 d
50	0		0.99±0.11 ^{CB}	1.13±0.12 ^{CB}	1.02±0.02 ^{EB}	1.27±0.23 ^{DB}	2.23±0.04 ^{CD} A
	2		1.48±0.06 ^{BD}	1.77±0.02 ^{ABC}	1.25±0.09 ^{CDE}	1.98±0.15 ^{BB}	2.08±0.01 ^{DA}
	4		1.86±0.20 ^{ACD}	2.08±0.06 ^{ABC}	1.47±0.06 ^{BCD}	2.47±0.45 ^{AB}	2.73±0.19 ^{AA}
100	0		1.10±0.01 ^{CC}	1.36±0.06 ^{BCB}	1.08±0.06 ^{CC}	1.35±0.02 ^{CCB}	2.26±0.20 ^{CD} A
	2		1.42±0.07 ^{BBC}	1.48±0.26 ^{BCB}	1.20±0.17 ^{CDC}	1.47±0.05 ^{CCB}	2.34±0.05 ^{BCD} A
	4		1.71±0.23 ^{AB}	1.71±0.09 ^{AB}	1.70±0.16 ^{AB}	1.63±0.05 ^{BCB}	2.45±0.21 ^{ABC} A
150	0		1.45±0.05 ^{BC}	1.53±0.10 ^{BC}	1.13±0.16 ^{DD}	1.91±0.19 ^{BB}	2.57±0.18 ^{AB} A
	2		1.86±0.12 ^{AB}	1.82±0.72 ^{AB}	1.44±0.09 ^{BCD}	1.94±0.05 ^{BAB}	2.48±0.17 ^{ABC} A
	4		1.91±0.11 ^{AB}	1.86±0.34 ^{AB}	1.81±0.42 ^{AB}	2.57±0.09 ^{AA}	2.64±0.07 ^{AA}

^{abc}Mean values in the same column bearing different superscripts are significantly different (p<0.05).

^{ABC}Mean values in the same row bearing different superscript are significantly different (p<0.05).

Table 4 Effect of nitrite and GP on N-nitrosodimethylamine contents (mg NDMA/kg sample) in frankfurter products

Factors	NDMA (mg /kg)			
	Nitrite (mg/kg)	GP (g/100g)	Before <i>in vitro</i> digestion	After <i>in vitro</i> digestion
50		0	ND	2.48±0.76 ^{ab}
		2	ND	3.21±0.94 ^{abc}
		4	ND	2.88±0.94 ^{abc}
100		0	ND	2.17±0.32 ^c
		2	ND	1.69±0.01 ^c
		4	ND	2.38±0.33 ^c
150		0	ND	3.30±0.10 ^{abc}
		2	ND	4.19±0.90 ^{ab}
		4	ND	4.26±1.13 ^a

^{abc}Mean values in the same column bearing different superscripts are significantly different (p<0.05).

ND = Not detectable

Table 5 Effect of nitrite and GP on sensory quality of frankfurters

Nitrite (mg/kg)	GP(g/100g)	Color	Odor	Taste	Texture	Overall acceptability
50	0	5.10±1.68 ^{bc}	5.30±1.75 ^{ns}	5.85±1.78 ^a	4.85±1.76 ^{ab}	5.85±1.39 ^a
50	2	6.50±1.47 ^a	5.50±1.64 ^{ns}	3.95±1.47 ^{bc}	4.15±1.70 ^{ab}	4.85±1.27 ^{ab}
50	4	5.95±1.85 ^{ab}	5.35±1.81 ^{ns}	5.00±1.72 ^{ab}	5.10±1.94 ^a	5.40±1.96 ^{ab}
100	0	4.65±1.18 ^c	5.35±1.78 ^{ns}	4.85±1.60 ^{abc}	4.70±2.05 ^{ab}	4.90±1.48 ^{ab}
100	2	6.00±1.95 ^{ab}	5.30±1.72 ^{ns}	4.65±1.42 ^{bc}	4.50±1.76 ^{ab}	5.15±1.56 ^{ab}
100	4	5.70±1.75 ^{abc}	5.25±1.37 ^{ns}	4.45±1.90 ^{bc}	4.75±2.07 ^{ab}	4.80±1.83 ^{ab}
150	0	4.70±1.62 ^c	5.45±1.76 ^{ns}	4.40±1.70 ^{bc}	3.75±1.48 ^b	4.75±1.48 ^{ab}
150	2	5.05±2.11 ^{bc}	4.65±1.78 ^{ns}	4.20±1.80 ^{bc}	4.05±2.00 ^{ab}	4.75±1.80 ^{ab}
150	4	5.80±1.85 ^{abc}	4.85±1.81 ^{ns}	3.70±1.87 ^c	3.90±1.62 ^{ab}	4.25±1.77 ^b

^{abc}Mean values in the same column bearing different superscripts are significantly different (p < 0.05).

NS = Non-significant

CONCLUSION

GP successfully improved the color of frankfurter as can be observed from the results of sensory evaluation and supported by increasing of a* and b* values. However, high level of GP had slight effect to increase TBARS value and N-nitrosodimethylamine content in the products. Finally, it can be concluded that GP is an alternative way to improve color of frankfurter products. Nonetheless, the addition of GP more than 2g/100g may increase lipid oxidation and N-nitrosodimethylamine formation.

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