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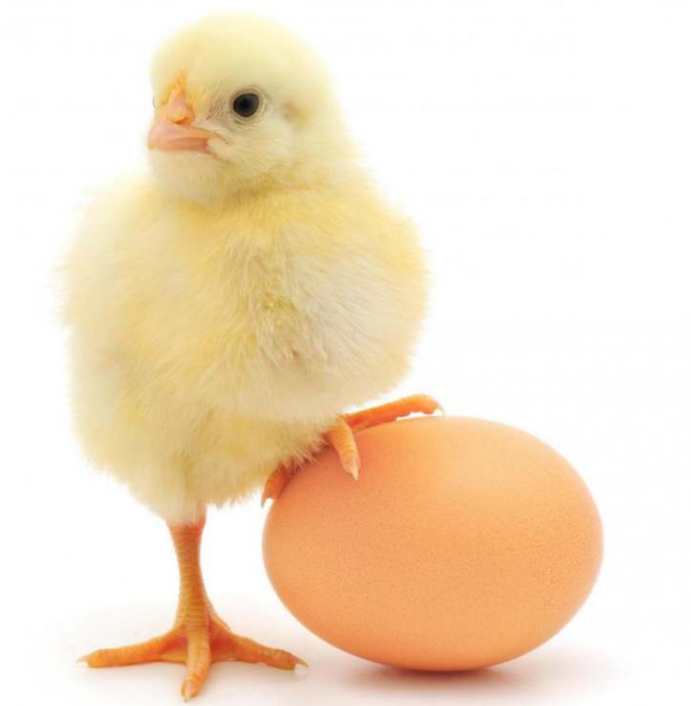

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Quality Characteristics of Spent Duck Sausages Containing Surimi Like Material Substitution During Refrigerated Storage

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Abstract: The quality characteristics of duck sausages prepared using different treatment were evaluated. Physicochemical, sensory and microbial properties of sausages containing duck surimi-like material substitution with cryoprotectant added (CPP) and without cryoprotectant added (NPP), antioxidant added (BHA) and, duck mince (as the control, CON) were compared. CPP and NPP sample had significantly higher ($p<0.05$) moisture content and lower protein and fat content compared with CON sample. The thiobarbituric acid-reactive substances (TBARS) value of all sample increased as the storage time increased up to day 30, but thereafter it decreased in all of the samples. CPP sample had significantly lower TBARS value ($p<0.05$) and this value remained lower than those of the other samples throughout the refrigerated storage time. Addition of duck surimi-like material to the sausages had significant effects ($p<0.05$) on hardness, gumminess and chewiness values of CPP and NPP sample. Treatment had no significant effect on sensory attributes of sausages prepared from duck meat. CPP sample had lower microbial activity during 40 days of refrigerated storage. However, BHA sample had no significant difference in microbial activity compared with CON sample. The results indicate that duck surimi-like material substitution with cryoprotectant added improves quality characteristics of duck sausages during refrigerated storage than the other treatments.

Key words: Sausages, physicochemical properties, sensory analysis, refrigerated storage, surimi-like material

INTRODUCTION

There are little information was available on utilization of meat from spent duck. In Malaysia, meat from spent duck is sold in the market at a lower price and meat obtained from these birds has poor functional properties. Spent duck meat is categorized as an underutilized poultry meat. One approach to increasing its value is to develop technologies to use the oversupply as human food. This meat also rare to be developed into emulsion-type and restructure products due to the some consumer's perception towards it's contains higher fat and possess strong ducky like flavor (Ismail *et al.*, 2010). Application of surimi technology could provide an opportunity to convert low-value duck meat with a limited market into a higher-value poultry meat protein source. Surimi/surimi-like material is composed mostly of myofibrillar proteins (Jin *et al.*, 2009), which may improve functional properties (for example, gelation properties) of meat products containing surimi/surimi-like material (Nurkhoeriyati *et al.*, 2012).

Commercial sausages produced in Malaysia, mostly in frozen form, are generally made from chicken, beef and fish (Huda *et al.*, 2010b). However sausage produced from duck meat has not been introduced yet in Malaysia market. During storage, quality attributes of the product deteriorate due to lipid oxidation and microbial growth. Lipids oxidation is responsible for reduction in nutritional quality as well as changes in flavor (Aguirrezábal *et al.*, 2000), while microbial contamination can precipitate major public health hazards and economic loss in terms of food poisoning and meat spoilage (Sallam *et al.*, 2004). Thus, application of suitable agents possessing both antioxidant and antimicrobial activities may be useful for maintaining meat quality, extending shelf-life and preventing economic loss (Yin and Cheng, 2003).

To date, most previous studies have focused independently on preservatives agent in preserving meat products and the objective of the present study was to investigate the effect of surimi-like material substitution on the physicochemical, sensory and microbial properties of spent duck sausages during refrigerated storage.

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MATERIALS AND METHODS

Duck meat samples: Khaki Champbell spent ducks weighing 1.5-2.0 kg (20-22 months old) were bought from a local farm located in Kulim, Kedah, Malaysia. The carcasses were mechanically deboned at Fika Food Corp. Sdn. Bhd., Malaysia, using a deboning machine with a pore size of 0.9 mm (Meat Maker Deboner, Prince Industries Inc., Murrayville, Georgia, USA). The meat was formed into blocks that were kept at -18°C prior to use.

Chemical and ingredients: Antioxidant (butylated hydroxyanisole) and food grade sodium tripolyphosphate (STPP) were bought from a local supplier (Euro chemo-pharma, Sdn Bhd, Penang, Malaysia). Polydextrose used in the sausage preparation was a super improved food grade polydextrose powder (Danisco Sweeteners Inc., Thomson, Illinois, USA). Other ingredients in sausage preparation such as cooking oil, salt, sugar, wheat flour, white pepper, garlic powder and coriander were purchased from a local market.

Preparation of duck surimi-like material: The mechanically deboned duck meat was constant in all duck sausage samples. Duck sausage with only mechanically deboned duck meat was served as control (CON). The duck sausages were prepared and tested with the following: (i) duck surimi-like material with cryoprotectant added (labeled as CPP); (ii) duck surimi-like material without cryoprotectant added (labeled as NPP); and (iii) mechanically deboned duck meat with antioxidant added (labeled as BHA).
Preparation of duck surimi-like material with and without cryoprotectant added: Preparation of the duck surimi-like material was generated based on the method described by Jin *et al.* (2007) and Zhou *et al.* (2006) with slight modification. The mechanically deboned spent duck meat was ground through a 2-mm grinder plate (Rheninghaus, Eve/All-12, Torino, Italy). The ground meat was washed with cold filtered tap water (4°C) at a ratio of 3:1 (v/w) water to ground meat with continuous stirring for 4 minutes with a mixer (Food Machinery Universal Mixer, B10-3, Kajang, Selangor, Malaysia). The mixture was then allowed to settle for 10 min. The topmost water layer was removed and the settled residue was centrifuged (Model Union 5 KR, Incheon, Korea) at 4000 rpm for 15 min at 4°C. The sample then was washed twice. Next, as a cryoprotectant, 6 g/100 g polydextrose and 0.3 g/100 g sodium tripolyphosphate were added to the washed mince (this cryoprotectant added step was negligible for the NPP sample preparation). The ingredients were mixed thoroughly with a silent cutter (Hobart, 84/45, Troy, Ohio, USA) for 1 min in a walk-in cold room. The duck surimi-like material mince was frozen using an air-blast freezer (BCF 51, Tansley, UK) and were kept at -18°C in sealed polyethylene packaging until use.

Preparation of duck sausage: The production of sausages was based on method espoused by Huda *et al.* (2010a) with a modification. Four types of duck sausages were produced in the present study as shown in Table 1. Each treatment was mixed with ingredients under air-conditioned temperature (14-16°C) for 3 min. Sausage emulsion was prepared using a meat processor (Robot Coupe Blixer grinder, France). The emulsion then was stuffed into 1.5 cm cellulose casing using a vertical sausage-filler and was tied manually at both ends. Samples were steam-cooked in a smokehouse (Kerres smoke air, Germany) to a core temperature of 72°C followed by cooling in ice flakes for 15 min. Cooked sausage samples were taken for analysis for study at 0th day. Other samples were vacuum packed (Audionva VMS 133, Malaysia) and stored in refrigerator (4°C) for study at 10, 20, 30 and 40th day of storage time.

Proximate composition: Moisture, protein, fat and ash contents were determined in accordance with standard AOAC methods (AOAC, 2000). Moisture was quantified by oven-drying 10 g duck sausage samples at 100-105°C overnight. Protein determination involved a Kjeldahl assay (Nx6.25). Fat was determined by extracting sausage in a Soxhlet apparatus using petroleum ether as a solvent. Ash was determined after incineration in a furnace at 500-600°C.

Thiobarbituric acid-reactive substances: Thiobarbituric acid-reactive substances (TBARS) were determined as described by Buege and Aust (1978). Ground sausage 0.5 g was mixed with 2.5 mL of a TBA solution containing 0.375% thiobarbituric acid, 15% trichloroacetic acid and 0.25 N HCl. The mixture was heated in a boiling water bath (95-100°C) for 10 min to develop a pink color, cooled with running tap water and then sonicated for 30 minutes, followed by centrifugation at 3500 rpm at 25°C for 20 min. The absorbance of the supernatant was measured at 532 nm. A standard curve was prepared using 1,1, 3, 3-tetramethoxypropane (MAD) at the concentration ranging from 0 to 10 ppm and TBARS were expressed as mg of malonaldehyde/kg sausage.

Texture profile analysis: This analysis was based on method of De Huidobro *et al.* (2005) with slight modification. Sausages were heated in a water bath at 90°C for 5 min and were uniformly cut into 1.5 cm thick. Texture of sausages were measured using a texture analyzer TA-XT2 (Stable Microsystem, UK), compression platen (SMS P/75) with a heavy duty platform ant the following settings: load cell, 25 kg; speed, 3.0 mm sec 1; test speed, 1.0 mm sec 1; post test speed, 3.0 mm sec 1; prefixed strain, 75%; time before sec compression, 2 sec. The following

Table 1: Formulation of duck sausages

	Treatment(g/100g)			
Ingredients	CON	BHA	CPP	NPP
Spent duck mince/MDDM	78.30	78.29	0	0
DSLM+cryoprotectant (polydextrose+STPP)	0	0	78.30	0
DSLM without cryoprotectant	0	0	0	78.30
Butylated hydroxyanisole	0	0.01	0	0
Wheat flour	3.65	3.65	3.65	3.65
Cold water	5.50	5.50	5.50	5.50
Mixed ingredients[a]	12.55	12.55	12.55	12.55

[a]Mixed ingredients (g/100 g): White pepper 3.00, Garlic powder 3.00, Coriander 2.00, Salt 2.00, Cooking oil 1.55, Sugar 1.00.
MDDM: Mechanically deboned duck meat, DSLM: Duck surimi-like material, STPP: Sodium tripolyphosphate, CON: Control duck sausage (only mechanically deboned duck meat), BHA: Duck sausage with antioxidant added (mechanically deboned duck meat with butylated hydroxyanisole), CPP: Duck sausage with cryoprotectant (with duck surimi-like material substitution), NPP: Duck sausage without cryoprotectant (with duck surimi-like material substitution).

Table 2: Proximate composition of duck sausages

Sample	Moisture (%)	Protein (%)	Fat (%)
CON	52.44±0.24[c]	16.31±0.32[a]	17.66±0.58[a]
BHA	55.26±0.86[b]	16.00±0.93[a]	18.34±1.88[a]
CPP	58.52±0.41[a]	14.17±0.78[b]	15.77±0.14[b]
NPP	59.34±0.11[a]	13.32±0.70[b]	14.85±0.10[b]

Mean value±standard deviation of the mean.
a-c: Means with different superscripts within the same column differ significantly at p<0.05
Refer to Table 1 for abbreviations

parameters were determined: hardness, cohesiveness, springiness, gumminess and chewiness.

Cooking yield: Cooking yield was determined by weighing the product before and after cooking and corresponds to weight loss due to heating. The percent loss in weight during the precooking treatment is reported as "cooking yield, %" (Candogan and Kolsarici, 2003):

Cooking yield (%) = (weight of cooked sausage/weight of uncooked sausage) x 100

Color analysis: Sausages were sliced into 5 mm thick. The color of sausage was measured internal and external using a colorimeter (Minolta CM 3500d, Japan). Spectrophotometer was calibrated using zero calibration box (CM-A 100) and followed by the white calibration plate (CM-A 120). The color reading includes lightness (L*), redness (a*) and yellowness (b*).

Sensory evaluation: Sausages were cut into uniform sized pieces and served warm (~50°C) to 30 member of panelists. Panelists were staff and graduate students who were trained in the use of attributing rating scale for the characteristics tested and were experienced in sensory evaluation of various foods (Larmond, 1977). All samples were coded with random three-digit numbers and the order of sampling was alternated to avoid positional bias. All panelists were regular meat consumers. Samples were scored for the attributes of color, odor, taste, texture and overall acceptance using a seven-point hedonic scale. Scores were assigned with 7 being like extremely, 6 being like moderately, 5 being like slightly, 4 being neither like nor dislike, 3 being dislike slightly, 2 being dislike moderately and 1 being dislike extremely.

Microbial analysis: Bacterial counts were determined by pour plate method espoused by Andrés *et al.* (2006). The initial dilution was made by aseptically blending 10 g of sausage with 90 mL 1 g/L peptone solution (EMD Buffered peptone water granulated, EMD Chemicals Inc. Gibbstown, N.J., USA) in a laboratory homogenizer for 1 min (AM-5 Ace homogenizer, Nihonseiki, Japan). The serial dilutions 10^1, 10^2, 10^3, 10^4 and 10^5 were plated duplicate with Plate Count Agar (EMD Dehydrated plate count agar granulated, EMD Chemicals Inc.) for total mesophilic aerobic count (incubated at 37°C for 2 days) and Potato Dextrose Agar (EMD Dehydrated potato dextrose agar granulated, EMD Chemicals Inc.) was used for mold and yeast counts (incubated 5 days at 30°C). Total plate count (TPC) data were expressed as log colony forming units (CFU)/g sausage. Yeast and mold counts were expressed as estimated aerobic plate count (EAPC)/g sausage.

Statistical analysis: The trial was performed twice and each trial was run in triplicate. The results were expressed as mean value±standard deviation. Physicochemical and sensory parameters were studied by one-way Analysis of Variance (ANOVA) and a Duncan test for multiple mean comparisons. Data were processed using SPSS version 17.0. The level of significance was 95%, i.e., $p<0.05$. Pearson correlation method was used to analyze correlations between parameters at significance levels of 0.05 (SPSS, 2008). Sensory data and all sample variables were further analyzed using principal component analysis (PCA), which was carried out using XLSTAT 2013 (Addinsoft Inc., New York).

RESULTS AND DISCUSSION

Proximate composition: Proximate composition of spent duck sausages are presented in Table 2. Moisture content was higher but fat and protein content was lower ($p<0.05$) in CPP and NPP sample compared to duck sausage sample without duck surimi-like material substitution (CON and BHA). Low level of fat and protein in both CPP and NPP sample was expected, resulted from the washing process carried out in duck surimi-like material mince. Previous work on the successive washing on duck meat, the results obtained showed that fat and protein content was lower compared to unwashed ones (Ismail *et al*., 2010). Ramadhan *et al*. (2011) reported that washing was significantly reduced the fat and protein content of duck meat from 22 to 5% and 11 to 9%, respectively. Addition of the antioxidant in BHA sample did not cause any significant changes ($p>0.05$) in protein and fat contents compared to CON sample. The fat values obtained for all duck sausage samples were within the permissible limit. The Malaysian Food Regulation of 1985 (Act 281) stated that manufactured meat should not contain more that 30% of fat (Law-of-Malaysia, 2004).

Thiobarbituric acid-reactive substances analysis: Lipid oxidation of duck sausage samples during refrigerated storage was evaluated by monitoring secondary oxidation compounds (TBARS). TBARS is a secondary oxidation compound commonly used as a measurement of lipid oxidation. Lipid oxidation is an important quality parameter for meat and meat products, as it may lead to rancidity (Jin *et al*., 2009). TBARS values of all duck sausage samples increased as the storage time increased up to day 30 ($p<0.05$). Thereafter, the decreases in TBARS values were obtained in day 40 (Fig. 1). According to Maqsood and Benjakul (2010), decreased in TBARS values were probably due to the losses in secondary oxidation compounds formed, particularly the low molecular weight volatile compounds. Malonaldehyde and other short-chain carbon products of lipid oxidation are not stable and are most likely decomposed to organic alcohols and acids, which are not determined by the TBA test (Borneo *et al*., 2009; Fernandez *et al*., 1997). Additionally, the decrease in TBARS was also due to the interaction of thiobarbituric acid (TBA)-reactive substances with proteins (Fernandez *et al*., 1997).

The CPP, BHA and NPP samples displayed the lower TBARS values as compared to CON sample throughout the storage period of 40 days. Therefore, the use of surimi-like material (in CPP and NPP sausage) and antioxidant (in BHA sausage) was effective in retardation of the lipid oxidation in duck sausage samples. TBARS values of the CPP sample were found to be the lowest, followed by BHA and NPP samples. The result indicated that duck surimi-like material with cryoprotectant added (polydextrose and sodium tripolyphosphate) was more effective than antioxidant (butylated hydroxyanisole) in preserving duck sausage from lipid oxidation during refrigerated storage at 4°C ($p<0.05$). Low amount of TBARS value in CPP sample was due to the present of phosphate (sodium tripolyphosphate) in the formulation. Phosphate in connection with salt will reduce the lipid oxidation and rancidity (Heinz and Hautzinger, 2007).

According to Tang *et al*. (2001) and Bhattacharyya *et al*. (2007), lipid oxidation is closely related to fat levels and the higher the amount of fat, the greater the TBARS values. However, in this study, the fat content and TBARS values for all sausage samples had positive weak correlation ($r = 0.144$, $p>0.05$). Thus, present study

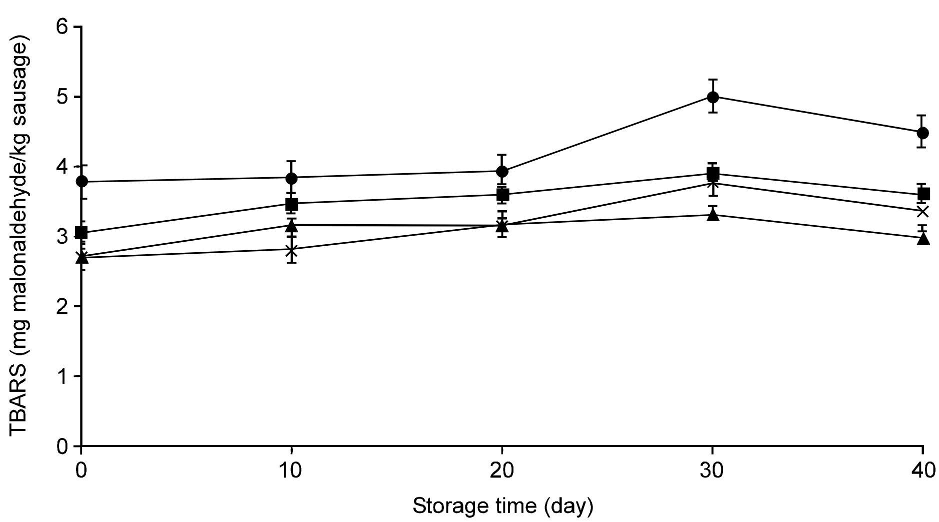

Fig. 1: **TBARS values for BHA, CPP and NPP compared with CON. CON: control duck sausage (●), BHA: duck sausage with antioxidant (x), CPP: duck sausage with cryoprotectant (▲) NPP: duck sausage without cryoprotectant (■)**

suggests that there was no apparent relationship between fat content and lipid oxidation, although sausage sample that retain more fat had higher TBARS values (except BHA sample). This finding was in agreement with Jin *et al*. (2009) and Mielnik *et al*. (2002) who reported that TBARS value less influenced by fat content. Differently in BHA sample, it contains higher fat (18.34%) but lowers in TBARS value. This probably due to the antioxidant effect, because antioxidant acts to delay the lipid oxidation in food systems (Martinez-Tome *et al*., 2001; Ohshima *et al*., 1998).

Lipid oxidation is a leading cause of quality deterioration in meat and meat products. The oxidation greatly reduces consumer acceptability because of associated rancid flavors (Cross *et al*., 1987). According to Greene and Cumuze (1982), 0.6-2.0 mg MDA per kilogram of TBARS is the values expected to produce detectable off odors or off flavor. All samples in the present study have exceeded the maximum threshold limit of reported TBARS (2.0 mg MDA/kg sample) which were ranging from 2.70 to 4.98 mg MDA per kilogram sample. However, different result was obtained by Bhattacharyya *et al*. (2007), who reported that the TBARS values of the spent duck sausage stored at refrigerated temperature for 21 days have lower than the minimum threshold limit of 0.6 mg MDA/kg sample (range, 0.18 to 0.59 mg MDA/kg sample). Such differences in results likely are due to the different source of meat and method of preparation.

Texture profile analysis and cooking yield: Table 3 shows the effects of refrigerated storage time and treatment on the textural properties and cooking yield of duck sausages. The hardness of the duck sausage samples increased significantly ($p<0.05$) during storage. Higher values of hardness at each sampling day were observed for the CPP and NPP samples. This probably was because CPP and NPP samples were substituted by duck surimi-like material. Ismail *et al*. (2010) found that successive washing in duck surimi-like material was effective in removing fat. Figure 2 shows that the duck sausage samples with low fat content showed high hardness values. Mittal and Barbut (1994) reported that a decrease in fat produced an increase in sausage hardness. Because fat in the sausages may have provided some lubrication effect on the lower breaking force and hardness values (González-Viñas *et al*., 2004). Hardness values of duck sausage samples presented in Table 3 were lower than the maximum value reported for commercial chicken sausages marketed in Malaysia (range, 3.84 to 7.25 kg) (Huda *et al*., 2010b). According to Huda *et al*. (2010b), hardness is the most important

Table 3: Values of the hardness, cohesiveness, springiness, gumminess, chewiness and cooking yield of duck sausage

	Refrigerated storage time (day)				
Sample attributes	0	10	20	30	40
Hardness (kg)					
CON	2.71 ± 0.19^{Cb}	3.46 ± 0.01^{Ba}	3.59 ± 0.47^{Ba}	3.32 ± 0.36^{Ba}	3.60 ± 0.34^{Ca}
BHA	2.53 ± 0.02^{Cc}	3.19 ± 0.19^{Cb}	3.44 ± 0.05^{Bb}	3.60 ± 0.01^{Bb}	4.26 ± 0.44^{Ba}
CPP	$3.57\pm.0.04^{Ac}$	3.50 ± 0.06^{Bc}	4.63 ± 0.36^{Ab}	4.87 ± 0.22^{Aab}	5.26 ± 0.31^{Aa}
NPP	3.24 ± 0.08^{Bd}	3.78 ± 0.00^{Ac}	4.55 ± 0.38^{Ab}	4.59 ± 0.27^{Ab}	5.12 ± 0.14^{Aa}
Cohesiveness (ratio)					
CON	0.33 ± 0.01^{Aa}	0.31 ± 0.01^{Ab}	0.32 ± 0.02^{ABab}	0.33 ± 0.01^{Aa}	0.32 ± 0.00^{Cab}
BHA	0.29 ± 0.01^{Bb}	0.30 ± 0.01^{Ab}	0.30 ± 0.00^{BCb}	0.34 ± 0.01^{Aa}	0.34 ± 0.01^{Aa}
CPP	0.30 ± 0.02^{Bbc}	0.32 ± 0.01^{Aab}	0.29 ± 0.00^{Cc}	0.33 ± 0.01^{Aa}	0.33 ± 0.01^{ABa}
NPP	0.34 ± 0.03^{Aa}	0.31 ± 0.03^{Aa}	0.33 ± 0.01^{Aa}	0.30 ± 0.02^{Ba}	0.32 ± 0.01^{BCa}
Springiness (cm)					
CON	0.61 ± 0.02^{Aab}	0.58 ± 0.02^{Ab}	0.60 ± 0.02^{Aab}	0.64 ± 0.04^{Aa}	0.65 ± 0.04^{Aa}
BHA	0.56 ± 0.01^{Ab}	0.60 ± 0.04^{Aab}	0.57 ± 0.05^{Ab}	0.59 ± 0.04^{ABab}	0.66 ± 0.01^{Aa}
CPP	0.56 ± 0.06^{Aa}	0.58 ± 0.06^{Aa}	0.55 ± 0.03^{Aa}	0.63 ± 0.02^{Aa}	0.61 ± 0.02^{Aa}
NPP	0.60 ± 0.05^{Aa}	0.59 ± 0.01^{Aa}	0.58 ± 0.02^{Aa}	0.57 ± 0.03^{Ba}	0.63 ± 0.03^{Aa}
Gumminess (kg)					
CON	0.90 ± 0.07^{Bb}	1.06 ± 0.03^{ABab}	1.16 ± 0.21^{BCa}	1.09 ± 0.09^{Cab}	1.14 ± 0.11^{Ca}
BHA	0.73 ± 0.01^{Cd}	0.95 ± 0.10^{Bc}	1.04 ± 0.02^{Cc}	1.24 ± 0.03^{BCb}	1.46 ± 0.15^{Ba}
CPP	1.06 ± 0.07^{Ad}	1.10 ± 0.03^{Ad}	1.33 ± 0.11^{ABc}	1.59 ± 0.09^{Ab}	1.76 ± 0.11^{Aa}
NPP	1.09 ± 0.12^{Ad}	1.19 ± 0.10^{Acd}	1.52 ± 0.16^{Aab}	1.39 ± 0.15^{Bbc}	1.65 ± 0.01^{ABa}
Chewiness (kg.cm)					
CON	0.55 ± 0.04^{Ab}	0.62 ± 0.03^{Aab}	0.70 ± 0.13^{ABa}	0.70 ± 0.04^{Ba}	0.74 ± 0.05^{Ba}
BHA	0.41 ± 0.01^{Bd}	0.58 ± 0.10^{Ac}	0.60 ± 0.04^{Bc}	0.74 ± 0.04^{Bb}	0.95 ± 0.09^{Aa}
CPP	0.60 ± 0.05^{Ac}	0.64 ± 0.07^{Abc}	0.74 ± 0.04^{ABb}	1.01 ± 0.06^{Aa}	1.06 ± 0.10^{Aa}
NPP	0.65 ± 0.13^{Ac}	0.70 ± 0.08^{Abc}	0.88 ± 0.13^{Aab}	0.79 ± 0.12^{Bbc}	1.04 ± 0.05^{Aa}
Cooking yield (%)					
CON	84.60 ± 0.59^{Ca}	83.42 ± 2.07^{Ba}	84.22 ± 0.63^{Ca}	84.92 ± 3.00^{Ba}	83.40 ± 1.12^{Ba}
BHA	87.19 ± 1.27^{Ba}	82.46 ± 2.04^{Bb}	82.58 ± 0.46^{Db}	84.55 ± 0.45^{Bb}	79.08 ± 0.19^{Cc}
CPP	88.84 ± 0.72^{Aa}	89.58 ± 0.53^{Aa}	89.14 ± 0.39^{Aa}	88.75 ± 0.52^{Aa}	89.07 ± 0.70^{Aa}
NPP	89.06 ± 0.19^{Aa}	88.97 ± 0.35^{Aa}	88.12 ± 0.46^{Bb}	88.59 ± 0.46^{Aab}	88.44 ± 0.32^{Aab}

Mean value±standard deviation of the mean

A-D: Means with different superscript within the same treatment differ significantly at $p<0.05$. a-d: Means with different superscript within the same refrigerated storage time differ significantly at $p<0.05$

Refer to Table 1 for abbreviations

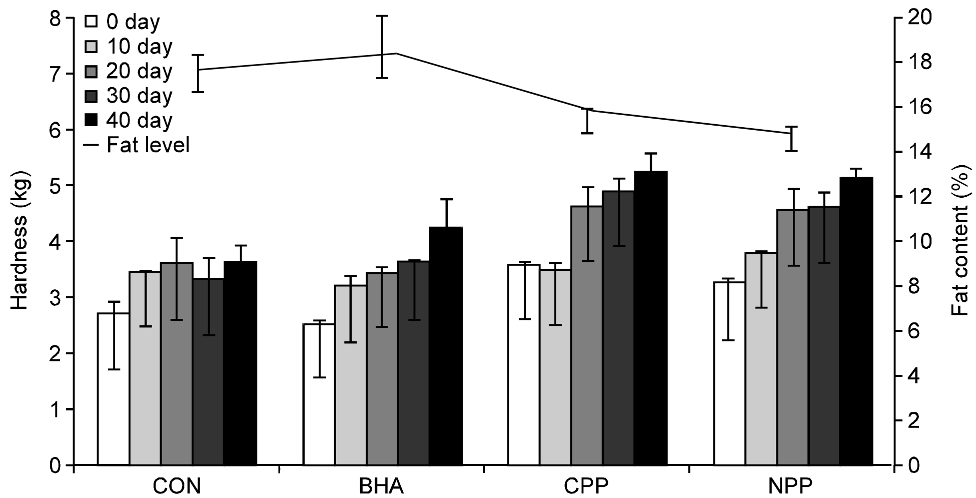

Fig. 2: Hardness values and fat content of duck sausage. Refer to Table 1 for abbreviations

attribute to the consumers among texture attributes, as it determine the commercial value of a meat/meat product. Dingstad *et al.* (2005) reported that, sausage samples with hardness value of 4.73 kg and above will have at least 60% of consumer willing to buy it. As a result, the hardness values of CPP and NPP samples that substituted with duck surimi-like material were found to be desirable compared to CON and BHA samples.

Antioxidant added sample (BHA) had no significant difference with cryoprotectant added sample (CPP) on the cohesiveness value throughout refrigerated storage time ($p>0.05$). Gumminess and chewiness in the reduced fat samples (CPP and NPP) were slightly higher compared with none duck surimi-like material substitution samples (BHA and CON), demonstrating that these values dependence on the increased hardness values. According to Cáceres *et al.* (2006) gumminess and chewiness behaved similarly to hardness. These values increased as the hardness value increased. Springiness of duck sausage samples had no significant difference ($p<0.05$) with storage time and treatment used.

Cooking yield in all duck sausage samples decreased over refrigerated storage time. Cooking yield was higher in duck surimi-like material substitution samples (CPP and NPP) than CON and BHA samples during each sampling day. Higher cooking yield in CPP and NPP sample was probably due to washing process in duck surimi-like material mince. This can be linked with the result reported by Yang and Froning (1992) in washed chicken mince. They reported that washing process increased the concentration of myofibrillar protein and caused higher in cooking yield. In this study, BHA sausage sample had the lowest value of cooking yield; thereby antioxidant added had no significant effect on the cooking yield of duck sausage during refrigerated storage. Substitution of duck surimi-like material and addition of cryoprotectant (polydextrose and sodium tripolyphosphate) in CPP sample had no significant difference ($p>0.05$) in cooking yield and this cooking yield value remained higher than the other samples at the end of refrigerated storage time. According to Sych *et al.* (1991) incorporation of cryoprotectants in surimi/surimi-like material were improved the gel-forming ability, increased protein solubility and increased cooking yield.

Color analysis: Color parameters for the different duck sausage samples are presented in Table 4 (inner surface) and Table 5 (outer surface). As can be seen, all measured color parameters were significantly affected by storage time. Both inner and outer L* values (lightness) declined during the refrigerated storage time. Duck sausage without any treatment (CON) had the lowest L* value both inner and outer surface among all of the samples. Compared with the CON sample, the L* value in the BHA sample was higher, but slightly lower than duck surimi-like material substitution samples (CPP and NPP). Thus, the substitution of duck surimi-like material may improve the lightness degree of duck sausage effectively than the addition of antioxidant. However, the L* values of antioxidant added sample (BHA) inner and outer surface had no significant difference ($p>0.05$) between day 10 and day 40 of refrigerated storage. This is probably attributable to the fact that, antioxidant was acted as an oxygen scavenger preventing undesirable changes in color or flavor (USDA, 2010).

Based on previous work, washing process was effective removed heme pigments (data not shown) and increased the lightness and whiteness of the duck mince (Ismail *et al.*, 2010). This finding was in agreement with others authors who reported similar

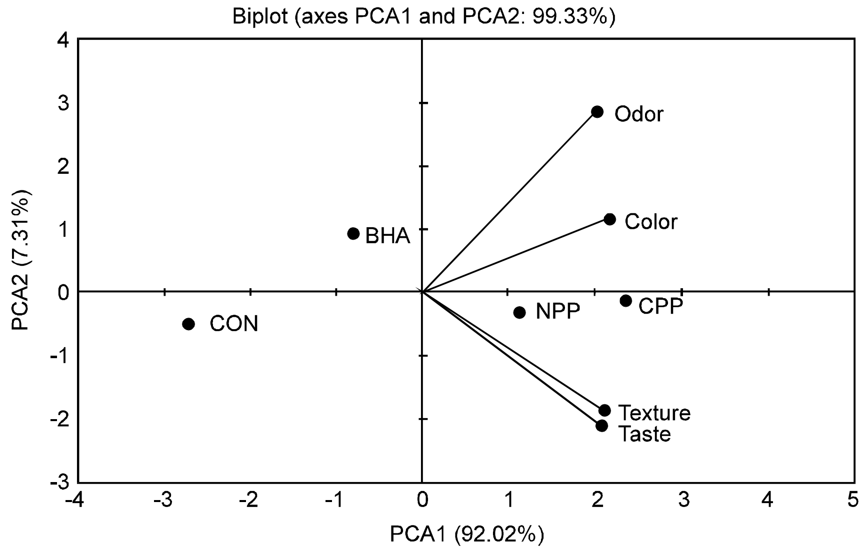

Fig. 3: Principal component analysis performed on the sensory data. Loadings and scores selected from factor 1 and 2 (PCA1 vs PCA2: biplot accounted for 99.33%). Refer to Table 1 for abbreviations

Table 4: L*, a* and b* values for inner surface of duck sausage

Sample	Week	L*	a*	b*
CON	0	53.76±0.10^{Ba}	2.11±0.04^{Ac}	17.16±0.44^{Ab}
	10	53.90±0.08^{Ca}	2.35±0.02^{Bb}	17.40±0.28^{Bb}
	20	52.82±0.03^{Cb}	2.45±0.01^{Bb}	17.50±0.08^{Bb}
	30	51.52±0.15^{Cc}	2.56±0.16^{Bb}	17.72±0.43^{ABb}
	40	50.33±0.71^{Bd}	3.23±0.19^{Aa}	19.19±0.58^{Aa}
BHA	0	54.67±0.22^{Ba}	2.05±0.09^{ABd}	16.51±0.33^{Bc}
	10	51.47±0.59^{Db}	2.70±0.03^{Ac}	18.19±0.31^{Ab}
	20	51.65±0.08^{Db}	2.91±0.12^{Abc}	18.37±0.69^{Ab}
	30	51.51±1.22^{Cb}	3.00±0.21^{Ab}	18.50±0.73^{Ab}
	40	51.18±0.08^{Bb}	3.30±0.06^{Aa}	19.75±0.46^{Aa}
CPP	0	56.82±0.11^{Aa}	1.96±0.05^{Bc}	15.91±0.10^{Cab}
	10	56.71±0.06^{Aa}	1.97±0.03^{Cc}	15.73±0.33^{Cb}
	20	56.46±0.28^{Aa}	2.19±0.04^{Cab}	15.98±0.40^{Cab}
	30	56.49±0.64^{Aa}	2.27±0.02^{Ba}	16.39±0.30^{Ba}
	40	53.97±1.52^{Ab}	2.10±0.11^{Cb}	16.31±0.30^{Bab}
NPP	0	56.79±0.24^{Aa}	2.07±0.02^{Ab}	16.11±0.07^{BCa}
	10	55.33±0.44^{Bb}	2.37±0.08^{Bab}	16.97±0.24^{Ba}
	20	55.45±0.98^{Bb}	2.44±0.05^{Ba}	16.55±0.36^{Ca}
	30	53.68±0.17^{Bc}	2.56±0.25^{Ba}	16.93±1.09^{Ba}
	40	53.84±0.39^{Ac}	2.68±0.29^{Ba}	17.28±0.91^{Ba}

Mean value±standard deviation of the mean
A-D: Means with different superscript within the same treatment differ significantly at $p<0.05$. a-d: Means with different superscript within the same refrigerated storage time differ significantly at $p<0.05$
Refer to Table 1 for abbreviations

Table 5: L*, a* and b* values for outer surface of duck sausage

Sample	Week	L*	a*	b*
CON	0	48.20±0.60^{Ca}	3.26±0.44^{Ac}	17.72±0.95^{Aabc}
	10	48.03±0.73^{Ba}	3.54±0.06^{Aabc}	17.40±0.27^{Abc}
	20	47.58±1.35^{Ba}	3.37±0.46^{Abc}	16.78±1.20^{Ac}
	30	47.64±0.24^{Aa}	4.06±0.28^{Aab}	19.20±0.69^{Aa}
	40	44.51±1.50^{Bb}	4.15±0.45^{Aa}	18.86±0.71^{Aab}
BHA	0	46.28±0.14^{Da}	2.96±0.18^{Ab}	17.58±0.26^{Aab}
	10	46.16±0.12^{Ca}	2.87±0.24^{Bb}	16.70±0.74^{Ab}
	20	45.46±0.17^{Ca}	3.24±0.37^{Ab}	17.89±0.46^{Aa}
	30	44.88±0.96^{Ba}	2.80±0.20^{Bb}	16.70±0.43^{Bb}
	40	45.50±1.27^{ABa}	3.75±0.39^{ABa}	17.76±0.69^{ABab}
CPP	0	54.01±0.41^{Aa}	1.92±0.08^{Bc}	14.32±0.34^{Bb}
	10	51.88±1.58^{Ab}	2.08±0.40^{Cbc}	14.92±0.86^{Bab}
	20	49.70±0.44^{Ac}	2.50±0.47^{Babc}	16.34±1.76^{Aab}
	30	47.28±0.23^{Ad}	3.00±0.61^{Ba}	16.93±1.68^{Ba}
	40	47.56±0.92^{Ad}	2.77±0.39^{Cab}	16.69±0.89^{Bab}
NPP	0	50.95±1.51^{Ba}	3.16±0.28^{Aa}	17.04±0.36^{Aa}
	10	50.71±0.46^{Aa}	3.24±0.05^{ABa}	17.31±0.25^{Aa}
	20	50.26±0.10^{Aa}	3.58±0.21^{Aa}	17.60±0.55^{Aa}
	30	47.94±0.44^{Ab}	2.55±0.27^{Bb}	15.43±0.86^{Bb}
	40	46.87±1.58^{Ab}	3.36±0.24^{BCa}	17.61±0.27^{ABa}

Mean value±standard deviation of the mean
A-D: Means with different superscript within the same treatment differ significantly at $p<0.05$. a-d: Means with different superscript within the same refrigerated storage time differ significantly at $p<0.05$
Refer to Table 1 for abbreviations

observation, where lightness values increased with the removal of heme pigments by washing process (Ensoy *et al*., 2004; Nowsad *et al*., 2000; Yang and Froning, 1992). These were evidence that, washing process were improved the L* values of CPP and NPP samples that substituted with duck surimi-like material. According to Resurreccion (2004) higher in L* value indicates a lighter color, which is desirable and has high consumer acceptance. Dingstad *et al*. (2005) reported that, at least 60% of consumers were willing to buy the sausage when L* value was between 62.3 and 68.5. In this study, the L* values of all samples (range, 44.51 to 56.82) were less than the reported values. However, lightness values of duck sausage samples were within the range published by Huda *et al*. (2010b) for commercial chicken sausages marketed in Malaysia (between 44.42 and 65.54).

Subsequently, redness (a*) and yellowness (b*) values fluctuated, but tended to increase during refrigerated storage. According to Fernández-Fernández *et al*. (1998), these fluctuations can be attributed to the spatial heterogeneity of the product (i.e., to the presence of

Table 6: Mean scores (n = 30) of sensory characteristics on a seven-point hedonic scale (7 = like extremely; 6 = like moderatety; 5 = like slightly; 4 = neither like nor dislike; 3 = dislike slightly; 2 = dislike moderately; 1 = dislike extremely) of spent duck sausages

Sensory characteristic	Color	Odor	Taste	Texture	Overall acceptability
CON	3.87^b (34.8)	2.70^b (8.70)	2.78^b (13.0)	3.09^b (26.1)	3.00^b (17.4)
BHA	4.57^{ab} (34.8)	3.48^a (21.7)	2.91^{ab} (17.4)	3.22^b (17.4)	3.26^b (17.4)
CPP	5.26^a (69.6)	3.83^a (34.8)	3.74^a (30.4)	4.35^a (43.5)	4.35^a (47.8)
NPP	4.91^a (56.5)	3.52^a (21.7)	3.65^{ab} (30.4)	3.91^{ab} (34.8)	4.17^a (47.8)
Average	4.65 (48.9)	3.38 (21.7)	3.27 (22.8)	3.64 (30.5)	3.70 (32.6)

a-b: Means with different superscript within the same column differ significantly at $p<0.05$. Percentage of panelists that scored each tested property between 5 and 7 is given between parentheses. Refer to Table 1 for abbreviations

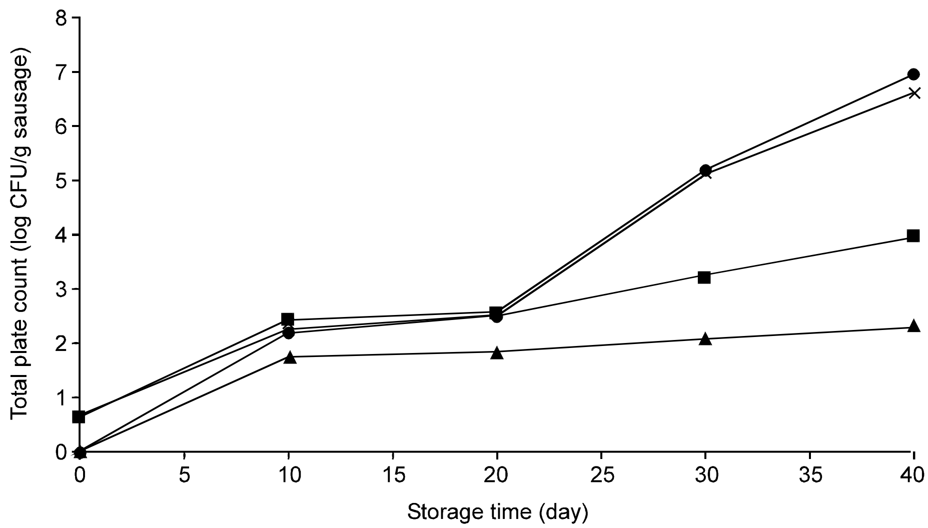

Fig. 4: **TPC values for BHA, CPP and NPP compared with CON. CON: control duck sausage (●), BHA: duck sausage with antioxidant (x), CPP: duck sausage with cryoprotectant (▲) NPP: duck sausage without cryoprotectant (■)**

pieces of fat and pieces of lean meat). The CPP sample had significantly lower a* values (both inner and outer) than the other samples ($p<0.05$). A lower in a* value could be related to a greater reduction of the heme pigments in the surimi-like material (Kristinsson and Liang, 2006).

Sensory evaluation: The 30 panelists evaluated the color, odor, taste, texture and overall acceptability of all 4 types of duck sausages (Table 6). In this study, treatment used had no significant effect on the mean sensory scores. Average scores for color, odor, taste, exture and overall acceptability were 4.65, 3.38, 3.27, 3.64 and 3.70, respectively (neither like nor dislike). Overall, less than 50% of the panelists liked the color, odor, taste, texture and overall acceptability of the duck sausages. The lowest mean score was observed by odor followed by taste attribute. According to Bhattacharyya *et al.* (2007), duck sausage scored less with respect to flavor due to an inherent duck-like odor and taste and this flavor could not be masked by the spices and condiments.

Figure 3 is a projection of the configuration of sausage samples in relation to the sensory analysis. Four sensory attributes were studied: color, odor, taste and texture. PCA1 is made up 92.02% of the variability while PCA2 accounted for 7.31%. The CPP and NPP samples are located in the same quadrant (positive side), whereas BHA and CON samples lie in different quadrant (negative side). According to the score plot, the CPP and NPP samples were evaluated as having higher sensory attributes score than BHA and CON samples, due to all sensory parameters contribute to the positive side of PCA1. However, pattern of distribution of all samples were pointed away from the vector line and these were linked to the lower mean scores of the panelists towards sensory attribute of duck sausage samples. This lower score was characterized by a high level of fat in the duck sausage samples. Because fat content is the main source of volatile compounds that influence the duck meat flavor (Soncin *et al.*, 2007). In conclusion, all duck sausage samples received lower overall liking scores. This could be due to the strong duck meat flavor and less attractive appearance of duck sausage samples that disliked by the panelists.

Microbial analysis: Initial total plate count (TPC) in the duck sausage samples were ranging from 0 to 0.66 log CFU/g sausage (Fig. 4). During the first 10 days of

Table 7: Yeast and mold counts for BHA, CPP and NPP compared with CON

	EAPC/g sausage				
Sample	0 day	10 days	20 days	30 days	40 days
CON	<100	<250	<250	<250	<250
BHA	<100	<250	<250	<250	<250
CPP	<100	<100	<250	<250	<250
NPP	<100	<100	<250	<250	<250

EAPC: Estimated aerobic plate count

<100 means plates with no colony forming units

<250 means plates with fewer than 25 colonies forming units

Refer to Table 1 for abbreviations

storage the microbial counts in all samples were still lower than 7 log CFU/g sample (i.e., maximum permissible limit of meat and meat products) for TPC recommended by Malaysian Food Regulation (Law-of-Malaysia, 2004). According to Andrés *et al.* (2006) low initial microbial counts were indicating a successful thermal processing (during preparation of chicken sausages), which inactivated most of the microorganisms. At day 40 of refrigerated storage, CPP and NPP samples have significantly maintained lower TPC i.e. 2.31 and 3.98 log CFU/g sausage, respectively. However, the microbial counts in CON and BHA samples were sharp increased after day 20 and close to maximum levels of 7 log CFU/g sample at day 40. Thus, addition of antioxidant (butylated hydroxyanisole) in BHA sample showed no significant effect in TPC when compared with CON sample. This finding was in agreement with Sallam *et al.* (2004) who reported similar observations. They found that chicken sausage with butylated hydroxyanisole added had no significant difference in microbial counts with control chicken sausage. In this study, we noted that duck sausage substituted with duck surimi-like material and cryoprotectant added (CPP sample) showed a consistent antimicrobial activity throughout the storage time. A higher antimicrobial activity in CPP sample could be due to the phosphate added (sodium tripolyphosphate) in the formulation. Because phosphates have antimicrobial activity and were used for improving the microbiological quality of muscle foods and to improve shelf-life (Molins, 1991). Molins (1991) also reported that changes in pH induced by phosphate addition may play an important role in the ability of these compounds to chelate metal ions essential in bacterial metabolism and growth.

Table 7 shows that yeast and mold counts increased with advancement of storage time in all duck sausage samples. Treatment had no significant effect on total yeast and mold during refrigerated storage. Yeast and mold counts were quite lower in all samples ranging from 0 to 23 CFU/g sausage. According to Bradford *et al.* (1993) inhibition of yeast and mold growth was probably a result of the growth of lactic acid-producing bacteria under anaerobic packaging conditions during refrigerated storage.

Principal component analysis: The plot of the PCA defined by factor 1 and 2 explained 43.97 and 30.46% of the total variance, respectively (Fig. 5a and b). Figure 5a is analogous to Figure 5b. Scores and loadings for the first two factors should be interpreted together. According to Mielnik *et al.* (2002) the score plot may be regarded as a map of samples, showing the location of the samples along each model component. It can be used to detect sample patterns, groupings, similarities or differences.

The first dimension in Figure 5a, the PCA1 differentiated very clearly between samples produced from duck surimi-like material (coded with CPP and NPP) at positive side and without duck surimi-like material (coded BHA and CON) at negative side. In this model, 43.97% of the variance in X (attributed as treatment and quality characteristic parameters) accounted for 30.46% of the variation in Y (attributed as storage time). The CON30 and CON40 samples sit at the upper left score plot, indicates a greater tendency for redness, yellowness, lipid oxidation and high microbial counts. In the same quadrant, the BHA40 sample characterized with a higher TPC, springiness and cohesiveness values. The CON and BHA samples that located at the lower left score plot attributed good correlation with protein and fat content. Increased in redness, yellowness, lipid oxidation, microbial counts, springiness and cohesiveness of CON and BHA samples can be linked to the storage time, because these variables were increased as the storage time increased (*Y*-loading of PCA1). In Figure 5b, the distributions on the score plot confirm the result of TBARS. The score plot reveals that TBARS and fat content were less correlated to each other and less apparent to be related to lipid oxidation. Thus, these quality attributes (redness, yellowness, TBARS, TPC, springiness, cohesiveness, protein and fat) had the highest contribution for the negative side of the first dimension.

In the positive side of the score plot, the CPP0, CPP10, CPP20, NPP0 and NPP10 samples were evaluated as having higher lightness, but this L* value decreased as the storage time increased (Y-loading of PCA1). These were characterized by the efficiency of washing process in the duck surimi-like material mince that caused the lighter color of CPP and NPP samples. A higher in cooking yield and moisture content were attributed by the CPP10, CPP20, NPP0, NPP10 and NPP30 samples. There were strong correlation between hardness, gumminess and chewiness at the upper right score plot. According to Andrés *et al.* (2006) gumminess and chewiness were dependence mostly the result of hardness. The NPP20, CPP30, CPP40 and NPP40 samples were having higher hardness, gumminess and chewiness characteristics. Thus, this texture attributes, lightness, cooking yield and moisture had the highest contribution for the positive side of the first dimension.

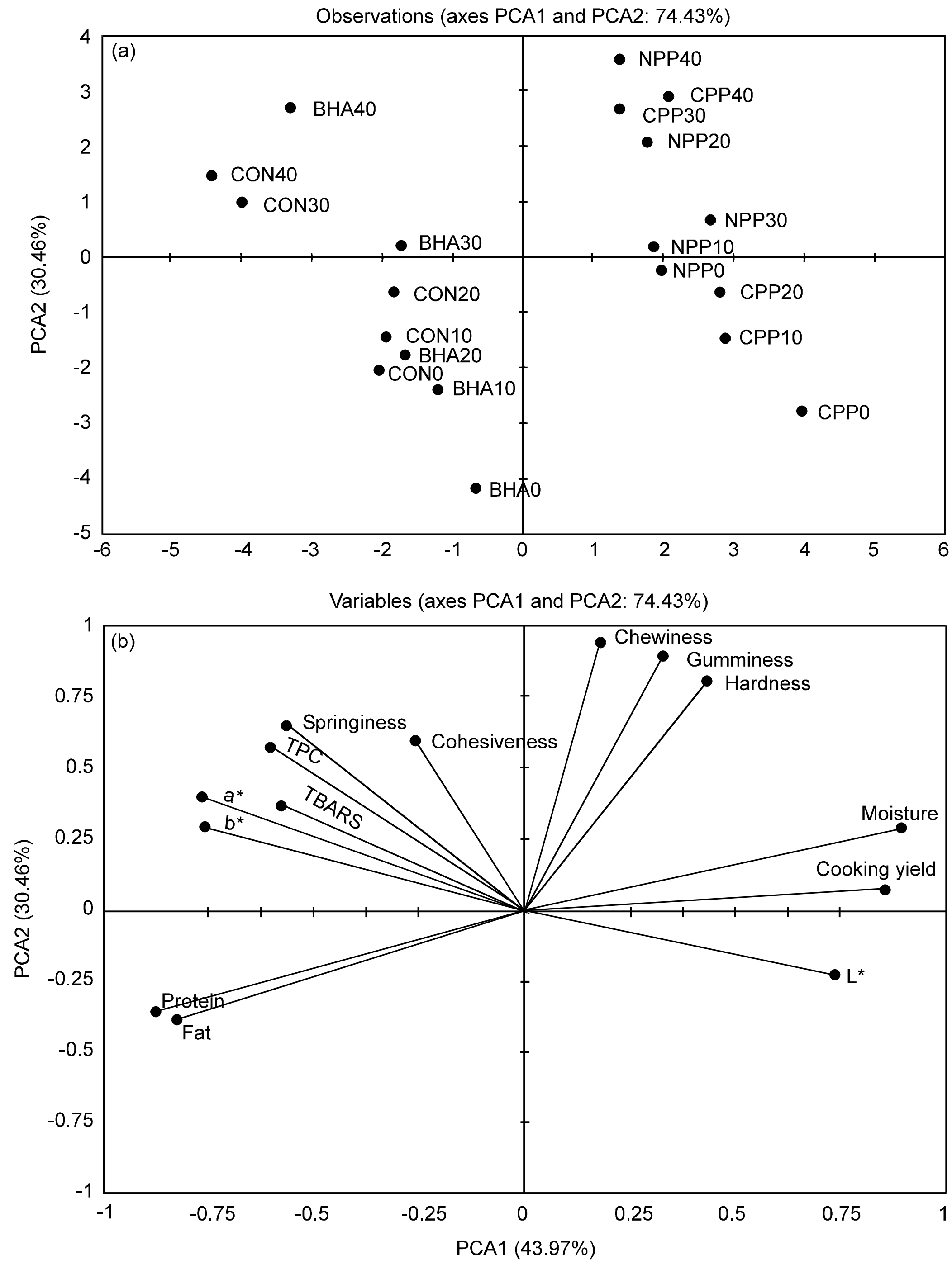

Fig. 5(a-b): Principal component analysis performed on the duck sausage variables. Loadings and scores selected from factor 1 and 2 (PCA1 vs PCA2: biplot accounted for 74.43%). Refer to Table 1 for abbreviations

It is concluded that the first factor (PCA1) was defined by the treatment used (with and without duck surimi-like material substitution) to influence the quality characteristics of duck sausage samples in relation to storage time.

The second dimension (PCA2) was mainly defined by texture attributes for the positive side and fat content for the negative side (Figure 5b). Protein content was omitted because they correlated closely with the fat content. The distributions on the score plot confirm the results from the texture profile analysis and fat content. The score plot reveals that hardness value and fat content were highly correlated to each other in opposite ways (r = -0.582, p<0.05). A decreased in fat content was increased the hardness value. Gumminess and chewiness values were based on the result of hardness. The NPP40, CPP40, CPP30 and NPP20 samples were characterized as having the hard, chewy and gummy texture and lower fat content. These texture attributes and fat content had the highest contribution for the positive side and negative side of the second dimension, respectively. Thus, the second factor was defined by the texture attributes closely linked to the fat content.

Conclusion: The substitution of duck surimi-like material and addition of cryoprotectant (6 g/100 g polydextrose and 0.3 g/100 g sodium tripolyphosphate) had significant positive effects on the quality characteristics of duck sausages. This study revealed that duck surimi-like material with cryoprotectant added improved physicochemical and sensory properties and reduced the microbial counts of spent duck sausages. Thus, this surimi-like material could be applied in sausage preparation and could improve stability of meat products during refrigerated storage.

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