

Effects of Humectant and Roasting on Physicochemical and Sensory Properties of Jerky Made from Spent Hen Meat

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Abstract

This study was carried out to develop jerky product utilizing spent hen meat. Manipulation of water activity (a_w) of semi-dried meat with the addition of humectants (glycerol and sorbitol at the concentration of 0, 10, and 15%) and roasting process were applied to enhance quality of jerky product. After spent hen meat was ground, formulated, reformed and then dried in convection oven at 85°C for 2 h followed by 60°C for 1 h, all jerky samples showed values of $a_w \leq 0.85$ with total aerobic bacteria, yeast and mold and *Staphylococcus aureus* counts were reduced to undetectable levels. Moreover, the results showed that the 15% glycerol added jerky showed superior quality, indicated by the lowest a_w , low protein aggregation as evaluated by sorption isotherm and the lowest shear value as compared to sorbitol added and control samples ($p < 0.05$). Regardless effect of humectant, roasting could improve the quality of the jerky via enhanced sensory attributes by increasing color, appearance, flavor and overall acceptability scores ($p < 0.05$). Therefore, spent hen meat could be used as a potential raw material for jerky in which soft product texture obtained by the addition of glycerol and intense flavor resulted from roasting process after drying, leading to sensory acceptance.

Keywords: spen hen, intermediate moisture meat, glycerol, sorbitol, sorption isotherm

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Introduction

Spent laying hens are considered a by-product of the egg industry (Kondaiah and Panda, 1992) and in Thailand they are commonly culled from herds after 70-80 wk of age mainly due to their low rate of egg production. These hens are referred to and marketed as "spent hens. Although meat obtained from spent hens is a good protein source, highly enriched with omega-3 fatty acids and low cholesterol content containing in breast muscle (Ajuyah *et al.*, 1992), its toughness due to increased cross-linking in the connective tissue of older animals (Bailey and Light, 1989) has precluded utilization in whole meat foods and has reduced its market value. Several researches have been made to tenderize spent hen meat with phosphate (Kondaiah and Panda, 1992), calcium chloride (Woods *et al.*, 1997), proteolytic enzymes from plant extracts (Navena and Mendiratta, 2001). The toughness of spent hen

meat is no obstacle to the production of a variety of comminuted products (Kondaiah and Panda, 1992), especially emulsified sausage, but emulsion stability and cooking yield were lower in spent hen meat than in broiler meat (Ilayabharathi *et al.*, 2012).

Using spent hen in meat emulsion product is a high initial investment, so it underutilize in some areas especially small-scale meat producer. Another group of meat product, jerky is known as a typical intermediate moisture meat (IMM) product and is relatively simple to process. Jerky products have been a favorite snack food popularly in the world with high nutritious (high in protein and low in fat), shelf-stable due to its low water activity (a_w) and no need refrigeration during commercial distribution (Allen *et al.*, 2007). Traditionally jerky has been made from thinly sliced whole muscles followed by marinated and dried, some type of jerky is made from ground meat, mixing with non-meat ingredients followed by forming into strips and then dried. To archive stability typically from microorganisms, jerky is dried to have a moisture content in the range from 10% to 40% (Taoukis and Richardson, 2007) particularly a_w level of ≤ 0.85 (Nummer *et al.*, 2004; USDS-FSIS, 2012). Meat contains approximately 75% water, which exists in three forms in the muscle;

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bound, immobilized and free, where a major portion is made up of free water (Huang and Nip, 2001). In general, a_w reduction by simple drying of meat results in too dry texture producing an oral sensation of dryness and reducing chewability of product (Taoukis and Richardson, 2007). One of the strategies used to stabilize the moisture content of IMM is an incorporation of humectants (Taoukis and Richardson, 2007). Since humectants are a substance that attracts water to itself, they can retain water in food-stuffs, reduce a_w and perform the important function of improving food softness. Among several types of them, glycerol and sorbitol are usually used to jerky process. Chen *et al.* (2000) found that shear force value of Chinese-style pork jerky reduced by increasing glycerol and sorbitol. Recently, Chen *et al.* (2014) pointed out that shear force value of Taiwanese venison jerky was decreased by the addition of glycerol and sorbitol. Not only texture but also flavor is important factors affecting consumers' decision on the quality of processed meat. Higher aroma and overall flavor intensity of roasted chicken than cooked sample had been reported by Dyubele *et al.* (2010).

At present, no published study has yet been made to investigate the use of spent hen meat for jerky processing. The purpose of this study was to investigate the feasibility of using underutilized spent hen meat in the production of jerky. The effects of humectants, glycerol and sorbitol, and roasting process on the physicochemical, microbiological and sensorial quality of jerky was also evaluated.

Materials and Methods

Meat preparation

Chilled carcasses of spent laying hens (approximately 80-90 wk of age including fattening period before slaughtering) were obtained from commercial slaughter plant, Jai Phue Phae Butchery, Nongjok, Bangkok, Thailand. These were manually deboned in the Department of Animal Production Technology and Fisheries, King Mongkut's Institute of Technology Ladkrabang (KMITL). Chilled carcasses were dressed according to Thai style retailed cutting. Breast, tenderloin and boneless thigh and drum of spent hen were collected, removed the skin, packed in polyethylene bags, stored at -20°C until further jerky processing (within 2 mon).

Study on jerky qualities as influenced by humectants

Jerky processing

Five jerky treatments, control (no humectants added),

10% glycerol, 15% glycerol, 10% sorbitol and 15% sorbitol were performed. The lowering level of humectants was previously trial, but no succeed to prevent toughness resulting from raw meat and drying was found. Three replications of each treatment were made for any differences among batches. According to manufactured jerky, frozen spent hen meat was thawed overnight in refrigerator at 4°C . Meat was cut to a small pieces and ground with grinder using a die with 5 mm holes. Five treatments of jerky were processed by using ingredients including 0.8% w/w sodium chloride (Thai Refined Salt Co., Ltd., Thailand), 4% w/w sugar (Mitrphol Co., Ltd., Thailand), 2% w/w soy sauce (ThaiTheparos Co., Ltd., Thailand), 0.2% w/w monosodium glutamate (Ajinomoto Co., (Thailand) Ltd., Thailand), 0.5% w/w barbecue seasoning (McCormick & Company, Inc., USA), 0.5% w/w paprika powder (McCormick & Company, Inc., USA) and different amount of 10% or 15% w/w glycerol (Chemipan Corporation Co., Ltd., Thailand) or 10% or 15% w/w sorbitol (Siam Sorbitol Co., Ltd, Thailand). After thoroughly mixed, 5 formulated treatments were reformed strips (30 mm \times 80 mm \times 5 mm) by a jerky gum equipped with a flat nozzle (LEM Jerky Gun, LEM Products Direct, USA). All treatments were cooked using a convection type hot air oven (FP115, Binder Inc., USA) at a temperature of 85°C until core temperature (CT) reached 71.1°C . Then the lower temperature, 60°C , was set for further dehydration till to a target $a_w \leq 0.85$. At 1 h intervals throughout drying, jerky samples were taken for monitoring temperature using insertion probe of Type-K thermocouple from a digital thermometer (52 Series II, Fluke Corp., USA) and recording a_w using a water activity meter (Novasina[®] LabMaster-aw, Axair Ltd., Switzerland). After drying and cooling to the ambient temperature ($25\text{-}30^{\circ}\text{C}$), the sample was weighed. Determination of drying yield was calculated by dividing the dried weight by the initial weight before drying and multiplying by 100. Moisture content was determined according to AOAC methods (AOAC, 2012). Samples were packed in heat-sealed bags for analysis of jerky quality.

Microbiological analysis

To ensure the microbiological safety of the present jerky process, total aerobic bacteria, yeast and mold and *Staphylococcus aureus* of raw meat and various 5 formulations of jerky products were carried out. Each sample (25 g) was transferred into 225 mL 0.1% peptone water (PW) and homogenized for 2 min with the Stomacher BagMixers 400 VW (Interscience Co., St. Nom, France). Appro-

appropriate ten-fold dilutions of the samples were prepared in PW and plated on growth media in duplicate to estimate microbial counts.

Total aerobic bacteria was determined by using pour plate method on Plate Count Agar (PCA) and the plates were incubated at 37°C for 24-48 h (BAM, 2001a). The counts of mold and yeast were determined by surface plating on Malt agar (MA) acidified with lactic acid and plates were incubated at 26°C for 3-5 d (BAM, 2001c). *S. aureus* was determined by surface plating on Baird-Parker Agar with added egg yolk tellurite emulsion and incubating the plates at 37°C for 24-48 h (BAM, 2001b). The number of colonies was counted and expressed as logarithms of colony forming units per gram (Log CFU/g).

Measurement of color and WBSF

Three randomly selected areas from an exterior color of jerky samples were measured in the L*a*b* mode of CIE. For WBSF measurement, the middle area of jerky samples approximately 10 mm × 30 mm × 5 mm were used to determine maximum force measured to cut the sample was expressed as Newton.

Texture profile analysis (TPA)

Pieces of dried meat samples measuring 10 cylindrical cores (Ø 10 mm with 10 mm long), reformed by the jerky gun with round nozzle, were placed parallel to the compression plate surface attached to an Instron universal testing machine model 3344. TPA textural parameters were measured at room temperature with the following testing conditions: crosshead speed was 60 mm/min and compressed twice to 40% of their original height. The Bluehill 2 software (Instron Engineering Corp., USA) was used to collect and process the data. TPA analyzes were defined and calculated as previously described by (Bourne, 1978). Hardness (N), cohesiveness (ratio), gumminess (N), springiness (ratio) and chewiness (N) were calculated from the force-time curves generated for each sample.

Sorption isotherm

Prior to study on adsorption isotherm, dehydrated jerky samples were prepared according to the methods of Yang *et al.* (2007) and Kim *et al.* (2010). Jerky samples were frozen at 80°C for 24 h and freeze-dried over 5 d. Dried samples were put into polystyrene weighing dishes and further dehydrated in vacuum desiccators over P₂O₅ for 5-7 d until constant weight was attained and the initial moisture content was recorded. Adsorption isotherm was carried out according to the operating instructions from

Novasina® LabMaster-aw using sorption isotherm set. Briefly, moisture adsorption isotherm was evaluated at 25°C over a range of relative humidity based on saturated salt solutions (11%, 33%, 53%, 75%, 90% and 97%). Every 2 h after humidification in various salt solutions, a_w and weight gain of a dehydrated jerky sample was detected. Moisture content (g H₂O/g solid) was calculated from the weight gain after absorbed moisture and was plotted against a_w, exhibiting adsorption isotherm.

Sensory evaluation

Sensory attributes in regard to color, appearance, texture, flavor and overall acceptability of the sample, were evaluated by 30 semi-trained panelists from undergraduate and graduate students of Department of Animal Production Technology and Fishery, KMITL using a seven-point hedonic scale. A score ranged from 1 to 7 with the following ratings: 7 = liked extremely, 6 = liked moderately, 5 = liked slightly, 4 = Indifferent, 3 = slightly disliked, 2 = moderately disliked and 1 = disliked extremely. Unsalted cracker and water were supplied to testers for refreshing their palates before tasting subsequent samples.

Study on jerky qualities as influenced by heat treatments

Because the best jerky formulation among various treatments was 15% glycerol (provided high jerky quality and sensory acceptance), this formulation was selected for studying the influenced of heat treatments. Jerky sample was processed in two types of heat treatments. The control treatment was dehydrated jerky in the convention oven until CT >71.1°C and a_w ≤ 0.85 as aforementioned processing detail. In the second heat method, dehydrated jerky was further roasted in a gas oven at the temperature of 180°C for 6 min. Quality among two jerky samples regarding drying yield, a_w, moisture content, color, texture profile analysis and shear force was compared. Sensory evaluation was performed by 30 semi-trained panelists from undergraduate and graduate students of Department of Animal Production Technology and Fishery, KMITL using a seven-point hedonic scale. Samples were assessed for their color, appearance, texture, flavor and overall acceptability.

Statistical analysis

Jerky qualities as influenced by the addition of humectants, results were carried out by the analysis of variance (ANOVA) and mean comparison was performed by Duncan's multiple-range test (Steel and Torrie, 1980). Regard-

ing the effect of heat treatment on jerky qualities, results were subjected to independent-samples *t*-tests. These statistical analyzes were performed by using the Statistical Package for Social Science (SPSS for Windows Version 11.5, SPSS Inc., USA).

Results and Discussion

Changes in temperature and a_w profile during drying process of jerky formulated with humectants

Two-step drying process of a jerky product from spent hen meat was developed in the present study. To produce microbiological safety of jerky as recommended by Nummer *et al.* (2004) and USDA-FSIS (2012), first cooked to attain CT above 71.1°C and then dried until $a_w \leq 0.85$ was expected. The result showed that after heating formed jerky strips under convection oven at 85°C for 2 h, the average of CT of all jerky was attained to about 73.55±0.45°C. Then jerky was subsequently dried in an oven at 60°C for 1 h to further dehydration, where the average CT of samples was 57.50±0.14°C. Previously trials pointed out that if high temperature was used through the process, desirable hard surface and brittle texture was produced. Moreover, a short period of total drying time of 3 h was found in the present study, which all jerky products meet the USDA-FSIS (2012) a_w recommendation as details below.

Changes in a_w values of samples were monitored during drying as shown in Table 1. Overall, all a_w values of jerky samples decreased rapidly during 3 h of drying ranged from 0.993-0.982 at the beginning to 0.854-0.630 at final dehydration depending on their treatments. Although values of $a_w \leq 0.85$ were detected in all jerky products (3 h of dehydration), which can inhibit growth of important bacterial pathogen including *Salmonella* spp., *Listeria monocytogenes*, *S. aureus* and *Escherichia coli* O157:H7 (USDA-FSIS, 2012), significant differences in a_w among samples were observed ($p < 0.05$). The addition of glycerol, especially 15% glycerol, into jerky formulation, provided the lowest a_w value ($p < 0.05$) followed by treatments of sorbitol and control, respectively ($p < 0.05$). Additionally, only the a_w value of 15% glycerol added jerky was 0.630, which was lower than a recommended a_w (≤ 0.70) to prevent mold growth during storage (USDA-FSIS, 2012). These results were similar to those previously reported by Chen *et al.* (2014) who study effects of glycerol and sorbitol on venison jerky and found that the a_w values of jerky treated with glycerol were significantly lower than those in sorbitol and control groups. Both of glycerol and

sorbitol are categorized as humectants in which they are compound capable to bind free water and decrease a_w of a solution or a product (Brown, 2008). As a comparison to the empirical constant (*K*) values as given by Norrish (1964), glycerol showed a lower *K* value ($K=0.38$) than sorbitol ($K=0.85$) indicative of their greater effect in lowering a_w (Ergun *et al.*, 2014). Thus, glycerol is more effective humectants in comparison with sorbitol to control a_w in jerky products processed from spent hen meat.

Validation of microbiological safety of jerky process formulated with humectants

The thermal process is among the most important factors controlling the microbial content and stability of finished product (Huang and Nip, 2001). The results indicated that total aerobic bacteria, yeast and mold and *S. aureus* counts of spent hen raw meat were found as 2.79±0.29, 2.56±0.03 and 2.77±0.04 Log CFU/g, respectively (Table 2). After drying at 85°C for 2 h (CT ~73.55°C) followed by 60°C for 1 h, total aerobic bacteria, yeast and mold and *S. aureus* counts of all jerky samples were reduced to undetectable levels. The results confirmed that present drying condition could produce microbiological safety products because it eliminated most organisms presented in the raw meat. For IMM with a_w values within 0.60-0.90, microbiological spoilage is usually the most important problem during storage (Huang and Nip, 2001). *S. aureus* is important photogenic bacteria because it has the ability to produce toxin at an a_w as low as 0.85 (Jay *et al.*, 2005). Due to the lowest a_w value of jerky added 15% glycerol, it may be safe from microbial growth.

Physicochemical characteristics of jerky formulated with humectants

Spent hen meat jerky samples showed significant differences in drying yield and moisture content ($p < 0.05$) as depicted in Table 1. The samples added with glycerol and sorbitol exhibited higher drying yield than control ($p < 0.05$). The moisture content of jerky sample significantly decreased with an increase level of either glycerol or sorbitol ($p < 0.05$). This results are in agreement with several researches which reported that the moisture content of various kinds of jerky products were decreased by the addition of glycerol or sorbitol (Boyle *et al.*, 1993; Chen *et al.*, 2000; Chen *et al.*, 2014) as well as sucrose (Chen *et al.*, 2002). In fact, water in foods exists in three general forms: (1) free, unbound water; (2) free, immobilized water; (3) chemically bound water. However, simple measurements of the water content (using drying oven) report

only free, unbound water and possibly a portion of free, immobilized water (Pennington *et al.*, 1990). After adding humectants in jerky formulation, they attract water to itself, might be bound as chemically bound water, so they potentially reduced the moisture content of products due to underestimation of water content.

Although the color of final products slightly differences among samples as shown in Fig. 1A, all humectants added jerky, except for 10% glycerol, possessed higher CIE L* value than control ($p < 0.05$) (Table 1). Values of CIE a* and CIE b* among samples were notably increased with an increase level of glycerol and sorbitol. Fernandez-Lopez *et al.* (2003) reported that the meat color is thought to be due to 3 factors, the concentration of heme pigments, chemical state of these pigments, and the physical light-scattering properties of the meat structure. Generally, humectants could attract water to itself resulting in low moisture levels and helps to prevent IMM from drying out, leading to increasing light-scattering and producing lighten finish product.

According to textural characteristics of jerky made from spent hen meat, only glycerol added jerky (10% and 15%) showed lower hardness and higher springiness as compared to control and sorbitol added treatment ($p < 0.05$) (Table 1). Lower gumminess and chewiness than control and sorbitol-treated jerky was detected in 15% glycerol treated sample ($p < 0.05$). Shear value of jerky samples was greatest decreased by the addition of 15% glycerol, followed by 10% of glycerol or 10% of sorbitol and 15% sorbitol or control, respectively ($p < 0.05$). Among the textural characteristics, hardness and chewiness are the most important sensory attributes of jerky-type foods and determines the uniqueness and markedly attractive of this type of products (Lee *et al.*, 2004). The results indicated that spent hen meat jerky, possessing tough meat background, should incorporate with 15% of glycerol for maintaining low chewiness, gumminess and hardness with high springiness value indicating soft and springy texture. These results are in agreement with Barrett *et al.* (1998), indicating that the glycerol can act as an effective textural plasticizer in certain meat products. Chen *et al.* (2000) reported that the shear force value of pork jerky decreased significantly with increased levels of glycerol rather than sorbitol. Vagenende *et al.* (2009) proposed that glycerol prevents protein aggregation by inhibiting protein unfolding and by stabilizing aggregation-prone intermediates through preferential interactions with hydrophobic surface regions that favor amphiphilic interface orientations of glycerol. However, 20% to 30% glycerol was reported to impart a

bitter taste (Boyle *et al.*, 1993).

Sorption isotherm of jerky formulated with humectants

Moisture adsorption curves of various jerky treatments processed from spent hen meat measured at 25°C were classified as Type III isotherms (Fig. 2) as found in several other foodstuffs rich insoluble components (Labuza and Altunakar, 2007). The resultant curve is due to high protein and carbohydrate content of jerky (data not shown). At low a_w , water content could be absorbed only at the surface sites. Increasing of a_w , generally higher than 0.8, results in the dissolution of the soluble component and brings about sharp increase in moisture content (Labuza and Altunakar, 2007). In the present study, jerky added with 10% and 15% glycerol could significantly modify the shape of the isotherm. In the range of 0.3 to 0.9, which is equivalent to an open storage relative humidity of 30% to 90%, jerky treated with glycerol had higher moisture content than those treated with sorbitol and control ($p < 0.05$), indicating good adsorption properties probably due to loosely packed protein network. These results are similar to those of Chen *et al.* (2000), who reported that glycerol increased absorption and sorbitol slightly decreased absorption of Chinese-style pork jerky. Since glycerol plasticized and expanded the protein network, the consequence of action was favorable to the adsorption of water molecules to jerky products. On the contrary, more aggregated protein from control and also sorbitol added jerky might act as barrier them to rehydration. Good humectants used in semi-dried meat products acts as both potential control and plasticized protein network, which was observed in glycerol regardless of sorbitol, could provide softer and high elastic texture of jerky. However, additional research is needed to elucidate the exact mechanism for fulfillment this observation.

Sorption isotherms are important for more than one reason including useful in the prediction of shelf-life. Molds can cause spoilage of jerky products during shelf life if the product acquires moisture from the environment (Nunmer *et al.*, 2004). Although the product gained the moisture from humid conditions, for example, it gained moisture up to 0.20% dry basis, the addition of glycerol (both 10% and 15%) could maintain the $a_w < 0.70$. Meanwhile, at 20% moisture content, sorbitol added jerky and control sample showed $a_w > 0.75$, which is a_w concerning of mold growth. It might indicate that glycerol could control the finished product from moisture pick-up, so that the a_w does not increase to an unsafe level.

Sensory evaluation of jerky formulated with humectants

The result of the sensory acceptance test is presented in Table 1. Jerky prepared by spent hen meat with 15% glycerol showed better acceptances in terms of color, flavor and overall acceptability than control sample ($p < 0.05$) and tended to be highest appearance and texture scores among treatments. There were no significant differences in sensory attributes between jerky treated with sorbitol (both 10% and 15%) and control ($p > 0.05$). It was observed that all values of the evaluated attributes were above the acceptance limit for the product (score 4 = Indifferent and 5 = liked slightly). Trindade *et al.* (2005) reported that the overall product quality decreased with the increase of spent hen meat percentage in the formulation of sausage. To achieve a higher sensory score of product in the present study, the process of roasting was used to combine into jerky processing as the details below.

Physicochemical characteristics and sensorial evaluation of jerky from different heat treatments

The superior jerky quality processed from sent hen meat, defined as the lowest a_w , soft and chewy textures, better

sensory acceptance, was found in jerky formulated with 15% glycerol. Therefore, this formulation was selected for further improvement of product quality, specifically sensory acceptance. The effect of two different thermal treatments of jerky processed from spent hen meats on drying yield, physicochemical properties and sensory attributes were evaluated. These results are shown in Table 3. There were no significant differences in drying yield, a_w , moisture content among samples ($p > 0.05$). Darker color as considered by lower CIE L* value was found in jerky produced by drying plus roasting as compared to one step of drying process ($p < 0.05$). More Maillard reaction between amino acid compounds and reducing sugar could promote darker and browned color of roasted jerky. Drying plus roasting process provided higher hardness and shear value of the jerky product than only drying process alone ($p < 0.05$). This result was influenced by the two thermal preparation accelerating water loss from the jerky product as concomitant with a tendency for low moisture content.

Higher sensory scores of color, appearance, flavor and overall acceptability was found in jerky processed by drying followed by roasting rather than drying alone ($p < 0.05$) (Table 3). There was no significant detrimental effect on

Table 1. Changes in a_w during drying and physicochemical characteristics and sensory attributes of jerky processed from spent hen meats from various formulations

Parameters	Control	10% Glycerol	15% Glycerol	10% Sorbitol	15% Sorbitol
Value of a_w during drying					
- 0 h	0.991 ± 0.00 ^{b,1,2}	0.993 ± 0.00 ^a	0.982 ± 0.00 ^d	0.987 ± 0.00 ^c	0.990 ± 0.00 ^b
- 1 h	0.973 ± 0.02 ^a	0.895 ± 0.01 ^b	0.795 ± 0.01 ^c	0.934 ± 0.04 ^a	0.946 ± 0.01 ^a
- 2 h	0.881 ± 0.03 ^a	0.791 ± 0.05 ^{ab}	0.702 ± 0.10 ^b	0.811 ± 0.10 ^{ab}	0.808 ± 0.03 ^b
- 3 h	0.854 ± 0.03 ^a	0.748 ± 0.01 ^b	0.630 ± 0.07 ^c	0.787 ± 0.01 ^{ab}	0.759 ± 0.04 ^b
Drying yield (%)	42.25 ± 0.81 ^b	45.81 ± 0.91 ^a	48.05 ± 0.47 ^a	47.88 ± 0.76 ^a	48.46 ± 0.85 ^a
Moisture (% wet basis)	36.54 ± 1.58 ^a	30.24 ± 1.32 ^b	24.96 ± 2.00 ^c	27.11 ± 0.59 ^{bc}	25.45 ± 2.41 ^c
Color					
- Lightness (CIE L*)	24.54 ± 0.10 ^b	26.83 ± 0.91 ^{ab}	28.24 ± 2.20 ^a	27.84 ± 0.38 ^a	28.18 ± 0.66 ^a
- Redness (CIE a*)	9.37 ± 0.30 ^c	10.00 ± 0.38 ^c	11.49 ± 0.22 ^a	10.35 ± 0.84 ^{bc}	11.18 ± 0.01 ^a
- Yellowness (CIE b*)	12.51 ± 0.04 ^c	13.47 ± 0.81 ^{bc}	15.99 ± 0.66 ^a	14.15 ± 0.90 ^{bc}	14.71 ± 0.68 ^{ab}
Texture Profile Analysis					
- Hardness (N)	35.34 ± 0.06 ^a	33.97 ± 2.99 ^b	29.12 ± 0.49 ^b	36.00 ± 3.17 ^a	38.69 ± 4.17 ^a
- Cohesiveness (ratio)	0.68 ± 0.02 ^a	0.70 ± 0.02 ^a	0.70 ± 0.01 ^a	0.62 ± 0.03 ^b	0.59 ± 0.03 ^b
- Gumminess (N)	24.47 ± 1.60 ^a	23.63 ± 1.93 ^a	20.38 ± 2.09 ^b	22.23 ± 2.54 ^a	23.57 ± 5.38 ^a
- Springiness (ratio)	0.78 ± 0.05 ^b	0.81 ± 0.02 ^a	0.81 ± 0.02 ^a	0.78 ± 0.02 ^b	0.74 ± 0.01 ^c
- Chewiness (N)	19.51 ± 0.35 ^a	19.15 ± 1.56 ^a	16.61 ± 0.91 ^b	18.78 ± 2.28 ^a	18.90 ± 5.24 ^a
Shear force (N)	36.69 ± 0.25 ^a	31.72 ± 0.46 ^{bc}	25.39 ± 0.83 ^d	30.68 ± 0.35 ^c	34.70 ± 0.50 ^{ab}
Sensory attributes					
- Color	4.27 ± 1.14 ^b	4.53 ± 1.17 ^{ab}	5.00 ± 1.16 ^a	4.67 ± 1.12 ^{ab}	4.53 ± 1.17 ^{ab}
- Appearance	4.17 ± 1.11 ^a	4.67 ± 1.29 ^a	4.70 ± 1.20 ^a	4.63 ± 1.19 ^a	4.63 ± 1.03 ^a
- Texture	3.70 ± 1.21 ^a	4.30 ± 1.20 ^a	4.40 ± 1.23 ^a	3.83 ± 1.31 ^a	4.27 ± 1.10 ^a
- Flavor	4.03 ± 1.15 ^b	4.57 ± 1.13 ^{ab}	4.77 ± 1.45 ^a	4.23 ± 1.34 ^{ab}	4.30 ± 1.21 ^{ab}
- Overall acceptability	4.13 ± 1.16 ^b	4.80 ± 1.15 ^a	4.80 ± 1.06 ^a	4.43 ± 1.17 ^{ab}	4.63 ± 1.00 ^{ab}

¹Values are given as means ± SD (n=3).

²Different superscripts in the same row indicate significant differences among treatments ($p < 0.05$).

Table 2. Microbial counts (Log CFU/g) of spent hen meat and jerky products from different formulations

Microbiological analysis	Raw meat	Jerky formulation				
		Control	10% Glycerol	15% Glycerol	10% Sorbitol	15% Sorbitol
Total aerobic bacteria	2.79±0.29 ¹	ND ²	ND	ND	ND	ND
Yeast and mold	2.56±0.03	ND	ND	ND	ND	ND
<i>S. aureus</i>	2.77±0.04	ND	ND	ND	ND	ND

¹Values are given as means±SD (n=3).

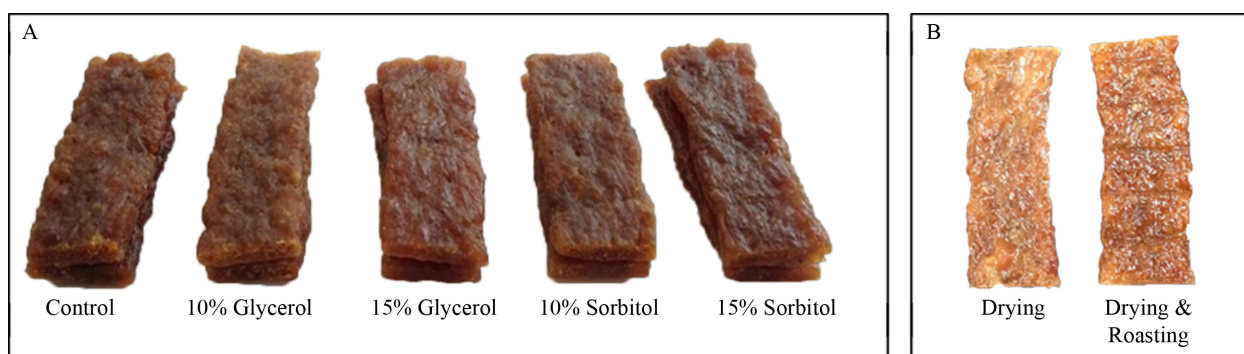
²Counts below the detection level.

Table 3. Physico-chemical characteristics and sensory attributes of jerky products processed from spent hen meats from different heat treatments

Parameters	Drying	Drying and Roasting
Drying yield (%)	47.23 ± 0.9 ^{a,1,2}	46.89 ± 0.01 ^a
Water activity (a _w)	0.603 ± 0.07 ^a	0.580 ± 0.03 ^a
Moisture (% wet basis)	22.61 ± 0.68 ^a	20.71 ± 2.67 ^a
Color		
- Lightness (CIE L*)	26.59 ± 1.63 ^a	20.19 ± 0.60 ^b
- Redness (CIE a*)	11.76 ± 0.34 ^a	12.01 ± 0.14 ^a
- Yellowness (CIE b*)	15.32 ± 0.14 ^a	14.34 ± 0.13 ^a
Texture Profile Analysis		
- Hardness (N)	25.74 ± 0.18 ^b	30.34 ± 0.12 ^a
- Cohesiveness (ratio)	0.71 ± 0.00 ^a	0.70 ± 0.01 ^a
- Gumminess (N)	22.03 ± 1.27 ^a	23.41 ± 0.42 ^a
- Springiness (ratio)	0.81 ± 0.01 ^a	0.79 ± 0.05 ^a
- Chewiness (N)	15.66 ± 0.93 ^a	16.39 ± 0.30 ^a
Shear force (N)	25.16 ± 0.35 ^b	30.69 ± 0.23 ^a
Sensory attributes		
- Color	4.20 ± 0.92 ^b	5.39 ± 0.85 ^a
- Appearance	4.47 ± 0.95 ^b	5.12 ± 0.95 ^a
- Texture	4.40 ± 1.08 ^a	4.10 ± 1.36 ^a
- Flavor	4.43 ± 1.06 ^b	5.16 ± 1.10 ^a
- Overall acceptability	4.45 ± 0.94 ^b	5.04 ± 0.94 ^a

¹Values are given as means±SD (n=3).

²Different superscripts in the same row indicate significant differences among treatments ($p < 0.05$).

**Fig. 1. Pictures of jerky products made from spent hen meat as influenced by humectants (A) and heat treatments (B).**

texture score as resulted from roasting ($p > 0.05$). During roasting, high Maillard reaction occurred and some of oil from glycerol that exuded from the jerky strips also increased, providing more desirable color, shining of jerky

surface as illustrated in Fig. 1B as well as intense flavor, thus increase palatability. Theses sensory attribute of roasted jerky scored between 5 (liked slightly) and 6 (like moderately) on the hedonic scale, which indicated higher

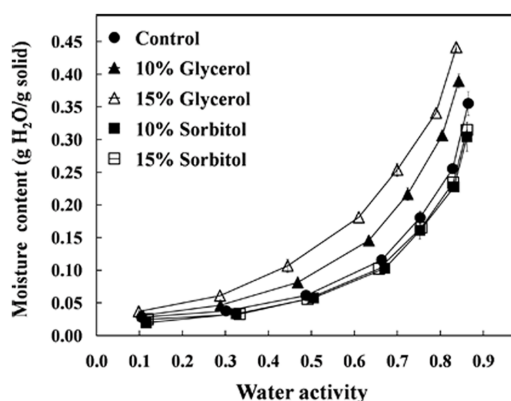


Fig. 2. Sorption isotherm of jerky products made from spent hen meat treated with humectants. Bars represent the standard deviation ($n=2$).

acceptance than drying process alone. Dyubele *et al.* (2010) also reported a significant effect of thermal preparation on sensory scores of chicken where the roasted meat possessed higher sensory scores of aroma intensity, initial impression of juiciness and overall flavor intensity than the boiled meat. The Maillard reaction, thermal degradation of lipids and Maillard-lipid interactions, are the main pathways by which a large number of flavor and aroma compounds responsible for desirable chicken meat flavor are formed during cooking (Jayasena *et al.*, 2013). Cooking methods such as roasting, grilling, frying, and pressure cooking generates many pyrazines, pyridines, pyrroles and thiazoles compared to boiling of chicken meat (Shi and Ho, 1994).

Conclusion

Spent hen meat could process to a jerky product with manipulation of a_w in semi-dried meat with humectant and combination of the roasting process. All jerky samples showed a_w values lower than 0.85 and amounts of total aerobic bacterial, yeast and mold and *S. aureus* were not detectable. The addition of 15% glycerol led to a superior jerky quality as defined by low a_w , soft and springy texture as well as lower protein aggregation as implied by sorption isotherm in comparison with control and also sorbitol. However, the combined roasting into jerky processing was also needed to improve sensory acceptances including color, appearance, flavor and overall product quality.

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