Quality changes of chicken meat jerky with different sweeteners during storage

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Abstract Chicken meat jerky with high sugar content is popular intermediate-moisture meat product in Asia. Different types of sugar, sucrose and mixed sugar (sucrose: fructose: sorbitol 70: 15: 15), were evaluated to improve the quality of product. Quality changes of chicken meat jerky stored in vacuum and aerobic (33 and 75 %relative humidity, %RH) conditions were studied for suitable condition to extend shelf-life of product. The samples were determined the physical and chemical characteristics, as well as sensory evaluation during storage at room temperature. The moisture content and water activity (a_w) of samples stored in 33 %RH conditions was continuously diminished during storage that related to harder texture and unacceptable quality in sensory evaluation. All samples stored in vacuum and 75 %RH condition demonstrated the lower shear force value than that stored in 33%RH condition ($p < 0.05$). Samples stored in vacuum condition had the lowest lipid oxidation ($p < 0.05$) which corresponding to the highest scores in less rancidity and overall acceptance attributes. All samples stored in vacuum condition also had the highest acceptability in all sensory attributes (taste, rancidity, color and overall acceptance) followed by 75 %RH storage condition ($p < 0.05$). Samples prepared with mixed sugar could improve color and retard rancidity in chicken jerky meat product. Sample prepared with mixed sugar kept in vacuum condition had the lowest lipid oxidation and highest sensory score in overall acceptance attributes along the extended storage.

Keywords Sweetener · Quality · Mixed sugar · Chicken meat jerky · Storage conditions

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Introduction

Chicken meat jerky classified in intermediate-moisture meat (IMM) product has water activity (a_w) ranged from 0.6 to 0.9 and moisture content in range of 10–50 % (Huang and Nip 2001; Roos 2001). The a_w or relative vapor pressure (RVP) of food normally has effects on food quality and food stability (Esse and Saari 2004; Fennema 1996; Troller and Christian 1978). Although foods had the same RVP, the different solute compositions exhibit different stabilities and properties in food (Esse and Saari 2004). Sweeteners used in jerky meat product for palatable sweet taste and preservation. Sucrose is general sugar used in this product. Mixed sugar including of fructose was applied in chicken meat jerky for browning development and reduction of glycemic index (Esse and Saari 2004; Roos 2001). Many factors dealing in chicken meat jerky manufacturer, for example, solute compositions in food, processing methods or humidity environments can particular change water in food product. The water availability on food stability depends on the types of interaction with solutes (Brannan 2008; Esse and Saari 2004).

Even if, IMM product is stable in microbiological hazards, however, the deterioration by chemical and physical reactions may occur readily in foods during storage (Loveday et al. 2009; Singh and Anderson 2004). Deterioration caused by chemical reaction in food during storage take place due to the breakdown of food components consists of lipids, proteins and carbohydrates. The extended storage of dehydrated foods may produce Maillard reaction and oxidative deterioration that has potential effect on color, flavor and texture of products (Singh and Anderson 2004). Maillard reaction caused a darkening of product, loss of flavor or undesirable changes in taste and texture of product during storage (Yang 1998).

Textural characteristics could be the main quality index of jerky product that indicated product instability during storage. Texture of jerky meat generally perform less juiciness and tougher or hardener because of water removal during thermal

processing (Chen et al. 2000; Engez et al. 2012; Yang et al. 2009). Textural change in food is associated with the moisture content and a_w of food (Chen et al. 2002; Troller and Christian 1978). Jerky made from lean meat may be too dry brittle, chewy and have undesirable to consumer (Yang et al. 2009). Sorbitol composing in mixed sugar can play humectant and stabilizer roles to soften the texture and reduce a_w of product (Chen et al. 2000). Water activity could effect on texture of food product. Tougher texture would be obtained when water activity of jerky product decreased below 0.75 (Esse and Saari 2004). Chen et al. (2002) concluded that pork jerky with high level of sucrose had significantly negative effects on protein solubility and extractability of myosin heavy chain due to Maillard reaction (Ajandouz et al. 2008).

Oxidative rancidity of lipids is the principal cause of deterioration of the quality of fried products during storage (Ramírez et al. 2004). Oxidative rancidity is the production of unpalatable flavors and odors due to secondary decomposition products such as aldehydes and ketones (Adams et al. 2009; Wong 1989; Xiao et al. 2011; Zamora and Hidalgo 2005). Mathlouthi (2001) concluded that lipid oxidation during storage generate below at a_w 0.30. At very low a_w ($a_w < 0.3$), the oxidation is high because an over-drying of sample subject to less than optimum stability (Fennema 1996). However, Troller and Christian (1978) reviewed that food containing unsaturated fats exposed to atmospheric oxygen are highly susceptible to oxidative rancidity development. Lipid oxidation is accelerated by the a_w especially, in the range of 0.3 to 0.7. Moreover, at a_w greater 0.8 region, water may retard rates of oxidation because dilution of catalysts reduce the effectiveness (Fennema 1996; Pomeranz 1991; Troller and Christian 1978).

The objective of this study was to investigate changes in quality and rancidity characteristics of chicken meat jerky prepared with different sweeteners stored at vacuum condition or humidity environment (33 and 75 %RH) conditions at room temperature. The different RHs of storage conditions, that is, 33 and 75 %RH, as well as vacuum condition were imitated the packaging conditions or displayed jerky meat product in market. All characteristics were determined together with the sensory evaluation.

Materials and methods

Materials

The frozen breast chicken meat was obtained from Saha Farms Company Limited (Songkhla, Thailand). Before sample preparation, the meat was thawed at 4 °C for 24 h and removed the skin, obvious fat and connective tissue. The breast chicken meat was ground using blender (MK-5086 M, Panasonic Co., Ltd., Malaysia) before preparing to sweet-dried chicken meat product. Sugar ingredients

consisted of sucrose, sorbitol and fructose, as well as salt were used as Food grade.

Chicken meat jerky preparation

The marinate sugar were set into 2 treatments: sucrose and mixed sugar (sucrose: fructose: sorbitol = 70: 15: 15). The ground meat was marinated directly with 2 % salt and 35 % sugar (by weight of meat). The mixture was held at 4 °C for 15 min before forming a sheet paste into size 4 cm × 6 cm × 0.3 cm with a plastic block. The sheet paste was preheated in air dryer at temperature of 45 °C until obtained 30 ± 3 % moisture content. After that, the dried sheet paste was deep-fried in palm oil at 120 °C for 8 min. Samples were cooled at room temperature and blotted the excess surface oil with towel paper. The chicken meat jerky were stored at room temperature in different conditions, that is, vacuum packaging (Nylon/LLDPE film), 33 %RH chamber (saturated $MgCl_2$) and 75 %RH chamber (saturated NaCl) for 1 month. The vacuum packing was done with vacuum instrument (Audion Elektro, Audionvac VM203, Holland). All samples were analyzed physical, chemical characteristics and sensory evaluation on day 0, 3, 7, 15, 22 and 31.

Moisture content

Moisture content of sample was analyzed in triplications by hot air oven (FD 115, Binder, Germany) at 105 °C (AOAC 1999).

Water activity (a_w) measurement

The blended samples were put into water activity cups, and determined in triplications using water activity meter (AquaLab 3TEB, Decagon, USA). The calibration was done at ambient temperature (25 °C) with distilled water ($a_w = 0.999$).

Texture analysis

The samples for shear force measurements were cut into size 2 cm × 3 cm × 0.3 cm using the Texture Analyzer (TA-XT 2i, Stable Micro System, UK) equipped with a Warner-Bratzler shear apparatus. The operating parameters consist of a cross head speed of 2 mm/s and a 50 kg load cell. The shear force was measured in ten replications for each treatment. The peak of the shear force profile was regarded as the shear force value (kg).

Thiobarbituric acid measurement (TBA)

The TBA of chicken meat jerky was determined by the distilled method (Tarladgis et al. 1960) as described by Ferrari

and Torres (2002). Briefly, 10 g of samples and 50 ml of distilled water was put in a beaker and was homogenized for 2 min. The homogenate was transferred to a Kjeldahl flask. Subsequently, 47.5 ml of distilled water, 2.5 ml of 4 M HCl, some anti-foaming drops and some glass beads were added. The mixture was distilled under intensive heating until 50 ml of distillate was collected in an Erlenmeyer flask. The flask was agitated. Five-milliliter aliquots were withdrawn and transferred to test tubes to which 5 ml of 0.02 M TBA in glacial acetic acid solution (90 % concentration) was further added. The test tubes were closed and heated in a water bath at 100 °C for 35 min. After cooling, absorbance at 538 nm was read using an UV–vis spectrophotometer (UV-1601, Shimadzu, Japan). The TBA amount was calculated by preparing 1,1,3,3 - tetraethoxy propane (TEP) standard curve as referred by Robles-Martinez et al. (1982). The TBA evaluation was done in triplications.

Sensory evaluations

Samples collected from each time of storage were served to 30 trained panelists for texture, taste, rancidity, color and overall acceptance evaluation using 9-points hedonic scales (1 = dislike extremely to 9 = like extremely). Panelists were asked to tear the samples before test or chewing in mouth. Panelists were required cleansing their palate between samples with water.

Statistical analysis

The completely Randomized Design (CRD) was used to study for physical and chemical analysis. The sensory evaluation was experimented with Randomized Complete Block Design (RCBD). All experimental data were analyzed by analysis of variance (Oneway-ANOVA). The statistical analyses were performed at a significant differences level of 95 % ($p < 0.05$) applied by Duncan's Multiple Range Tests (DMRT) among the means from triplicate for chemical characteristics and ten replicates for physical characteristics.

Results and discussion

Chicken meat jerky prepared with sucrose had lower moisture content than the sample prepared with mixed sugar on day 0 of storage ($p < 0.05$). This was probably because fructose and sorbitol composited in mixed sugar. Moisture content of samples stored at vacuum and 75 %RH condition had a little change during storage (Fig. 1). While, the samples kept at 33 %RH had distinctly decrease in moisture content when storage time increased ($p < 0.05$).

Figure 2 displayed a_w value of chicken meat jerky prepared with different sweeteners during storage in various conditions.

Fig. 1 Moisture content of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) storage in different conditions at room temperatures

The a_w value of chicken meat jerky prepared with sucrose was higher than that prepared with mixed sugar on day 0 of storage ($p < 0.05$). Samples prepared with sucrose and mixed sugar stored at vacuum and 75 %RH conditions had a slightly change in a_w ($p \geq 0.05$), while, the samples kept at 33 %RH was deeply decreased as prolonged storage time ($p < 0.05$) (Fig. 2). Those a_w values of all samples stored in various conditions were corresponding to the ERH in chamber (Fig. 2).

The chicken meat jerky prepared with sucrose had moisture content and a_w value equal 24.03 % and 0.668, respectively. Samples prepared with mixed sugar, containing sucrose, fructose and sorbitol, had moisture content 26.20 % and a_w 0.615. The addition of mixed sugar in product resulted in higher moisture content and lower a_w value compared to sample prepared with sucrose on initial of storage ($p < 0.05$). In mixed sugar, monosaccharides (fructose or sorbitol) have more free hydroxyl groups per sugar unit than disaccharides (sucrose) leading to increasing of water-soluble or hydrophilic characteristic (Ergun et al. 2010; Meste et al. 2006; Wrolstad 2011). Moreover, fructose and sorbitol had higher water absorption than sucrose because the property of hygroscopic sugar in water absorption when exposing to a given RH (Wrolstad

Fig. 2 Water activity of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) storage in different conditions at room temperatures

2011). With those reasons could explain the higher water content in sample prepared with mixed sugar. Additionally, sorbitol and fructose play the role of humectant that has the ability to resist changes in moisture content by attract water and maintain plasticity in a food system without producing hygroscopic effects. Amorphous sucrose is ineffective as a humectant because it will crystallize, lose its affinity for water, and result in loss of plasticity (Wrolstad 2011). The effect of sugar plasticity in mixed sugar could decrease a_w of sample prepared with mixed sugar lower than that prepared with sucrose.

The a_w value of the samples stored at vacuum and 75 %RH conditions increased over the storage time, while the moisture content had a slightly change. This might be due to the loss of colligative effect of sugars as they recrystallized leading to an increase a_w of samples. The samples stored at 33 %RH condition had an extremely decrease in moisture content and a_w value probably due to water mobility in food components to equilibrate RVP between water in sample and humidity around the environment (Fennema 1996; Meste et al. 2006).

The textural characteristic of chicken meat jerky regularly appears toughness (Chen et al. 2002). Figure 3 displayed shear force value of chicken meat jerky during stored in different conditions at room temperature. Shear force of chicken meat jerky prepared with mixed sugar was lower than that prepared with sucrose since day 0–7 of storage ($p < 0.05$). This might be due to the plasticizer effect of sucrose and sorbitol could tenderize the texture of jerky meat (Chen et al. 2000; Kim et al. 2010). Chen et al. (2000) indicated that shear values decreased with the addition of glycerol or sorbitol in pork jerky. Sorbitol has a plasticizing effect to improve the texture of the products because of their small molecular weight (Wang 2004). After day 15 of storage, samples prepared with sucrose and mixed sugar stored at 33 %RH condition had higher shear values than those stored in vacuum and 75 %RH condition ($p < 0.05$). Shear force values of samples stored in vacuum

and 75 %RH was not changed during storage which was coincident to a little change of moisture content ($p \geq 0.05$) as the extended storage time. The chicken meat jerky stored at 33 %RH condition had an increasing shear force values when the storage time increased ($p < 0.05$). After day 7 of storage, the shear force values extremely increased that corresponding to an exceedingly decrease in moisture content and a_w of product (Figs. 1 and 2). The high shear force value might be correlated with cross-linking of protein–protein (Ajandouz et al. 2008) or the lower moisture content (Chen et al. 2002; Yang et al. 2009).

The preferable liking in textural characteristic of chicken meat jerky was simultaneous determined sensory evaluation in texture attributes as performed in Fig. 4. The texture scores in sensory evaluation of all samples were decreased when the storage time increased ($p < 0.05$). The scores of samples prepared with sucrose and mixed sugar kept at vacuum and 75 %RH condition was gradually diminished as the prolonged storage time ($p < 0.05$) that ranged from like moderately to neither like nor dislike. Whereas, those samples stored at 33 %RH condition was substantially decrease after day 7 of storage ($p < 0.05$). The texture characteristic of samples stored in 33 %RH appeared in unacceptable that coincident with greater shear value and decreasing moisture content during storage.

However, the poor acceptable in texture attributes during storage of chicken meat jerky prepared with sucrose and mixed sugar stored at vacuum and 75 %RH conditions related to the higher shear force values approximately 1.7 to 2.5 kg (Fig. 3). Some factor variations in chicken meat jerky processing affected the texture of product such as ingredient compositions, storage condition, product instability, etc. Moreover, product instability related to moisture loss of product during storage leading to harder texture (Meste et al. 2006). Yang et al. (2009) proposed that the higher shear force of jerky might be correlated with the lower moisture content and muscle fiber composition.

Fig. 3 Shear force value of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) storage in different conditions at room temperatures

Fig. 4 Texture scores in 9-point hedonic sensory evaluation of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) stored in different storage conditions at room temperature

Spectrophotometric detection of the malonaldehyde-thiobarbituric acid (TBA) complex has been widely used for measuring lipid oxidation in food products. Figure 5 showed TBA values of chicken meat jerky during storage at various conditions. The results showed that TBA values of all samples decreased when the storage time increased ($p < 0.05$). The chicken meat jerky prepared with mixed sugar had lower TBA value than the samples prepared with sucrose which was corresponding to the rancidity scores in sensory evaluation of samples prepared with mixed sugar (Fig. 6). Since samples prepared with mixed sugar had higher extent Maillard reaction than samples prepared with sucrose because of an accelerating of reducing fructose (Laroque et al. 2008). Some derivative compounds produced by Maillard reaction in sample prepared with mixed sugar could retard lipid oxidation (Dong et al. 2011; Zamora and Hidalgo 2005). The lowest TBA value was observed in samples stored in vacuum condition ($p < 0.05$) which was confirmed by high sensory scores in rancidity attributes (Fig. 6). The least TBA value of samples stored at vacuum condition was showed in plateau line after day 7 of storage. This might be due to availability of oxygen clearly plays a critical role in determining competitive lipid oxidative pathways (Nawar 1998).

All samples stored at 75 %RH condition had the highest TBA value ($p < 0.05$). In storage condition of 75 %RH, oxygen and a_w might be the important factors to accelerate lipid oxidation. All samples stored in 75 %RH condition showed a_w in range of 0.6–0.7 (Fig. 2) that fastened lipid oxidation (Fennema 1996; Pomeranz 1991). Addition of a_w value ranged from 0.5 to 0.8 could accelerate lipid oxidation by increasing the solubility of oxygen and allowing macromolecules to swell that exposing more catalytic sites. Nevertheless, the lowest TBA values were observed in samples stored at 75 %RH condition on day 22 of storage probably due to the secondary oxidation products may have further degraded quickly to tertiary oxidation products (Kong et al. 2011).

Fig. 5 Thiobarbituric acid value (TBA, mg/kg sample) of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) storage in different conditions at room temperatures

Fig. 6 Rancidity scores in 9-point hedonic sensory evaluation of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) stored in different storage conditions at room temperature

Moreover, TBA values of those samples were increased again after day 22 of storage might be due to interferences of other aldehydes produced from Maillard reaction interacted with TBA (Fernández et al. 1997).

TBA values of samples prepared with sucrose and mixed sugar stored at 33 %RH condition changed in a similar trend that gradually decreased when the storage time increased ($p < 0.05$) (Fig. 5). The a_w value of those samples stored at 33 % RH condition decreased from 0.6 to 0.4 (Fig. 2). The rancidity scores in sensory test of samples prepared with sucrose and mixed sugar stored at 33%RH was not significantly different (Fig. 6). Lipid oxidation during storage generates below at 0.30 to 0.50 a_w . This might be due to water binds hydroperoxides with hydrogen bonds resulted to interfering with their decomposition and thereby hindering the progress of oxidation. In addition, metals are hydrates subjected to loss their capacity to catalyze the rate of lipid oxidation. Alternatively, catalysts are rendered ineffective by formation of insoluble hydroxides. Moreover, the initiation, production and stability of free radical decreased as water content increased (Fennema 1996; Mathlouthi 2001; Pomeranz 1991; Troller and Christian 1978).

TBA value of chicken meat jerky prepared with sucrose and mixed sugar showed the highest extent on day 0 of storage probably because of the preparation method of raw material. Mechanical disruption of the tissue induces membrane lipids to form much smaller vesicles, and the increasing of surface area accelerates lipid oxidation (Erickson 2007; Tang et al. 2001a). Moreover, unsaturated aldehyde in lipid oxidation can undergo autooxidation with oxygen giving rise a short-chain hydrocarbons, aldehydes and dialdehyde (Nawar 1998). Furthermore, salt addition in variety of meats accelerates lipid oxidation (Erickson 2007; Tang et al. 2001b). All samples with different storage condition had a decreasing TBA value during storage might be because malonaldehyde could form linear or cyclic Schiff's base or cross-linked bond

with lysine and arginine from proteins. Thus, the quantification of TBA value could be underestimating (Barriuso et al. 2013). However, the absence rancidity score was preferred in chicken meat jerky prepared with mixed sugar on the initial of storage. Samples stored at 33 and 75 %RH conditions had high rancidity than that stored in vacuum condition ($p < 0.05$) because the oxygen in humidity of environment of storage accelerated the lipid oxidation (Nawar 1998) (Fig. 6).

Taste scores in sensory evaluation of chicken meat jerky stored at different conditions showed in Fig. 7. The sensory scores in taste attributes of samples prepared with sucrose and mixed sugar was not different ($p \geq 0.05$). The highest taste scores were found at vacuum and 75 %RH storage conditions. The lowest taste scores were observed at 33 %RH condition. The sensory scores in taste and rancidity attributes of chicken meat jerky were decreased when the storage time increased ($p < 0.05$) (Fig. 6).

The color scores in sensory test of chicken meat jerky during storage are displayed in Fig. 8. Samples prepared with mixed sugar stored in different conditions had markedly higher color scores than that prepared with sucrose during day 0 to 15 of storage ($p < 0.05$). The color attribute of chicken meat jerky prepared with mixed sugar on day 0 to 7 of storage was preferred in like moderately to like extremely. The samples prepared with sucrose and mixed sugar store at vacuum and 75 % RH condition had highest color scores after day 15 of storage. Samples stored at 33 %RH condition had the lowest scores which performed in unacceptable.

Figure 9 displayed overall acceptance scores in sensory evaluation of chicken meat jerky stored at different conditions. The overall acceptance scores of chicken meat jerky prepared with mixed sugar was higher than the samples prepared with sucrose during day 0–3 of storage ($p < 0.05$). The sensory scores in overall acceptance of samples prepared with sucrose and mixed sugar stored at vacuum condition had the highest scores, followed by the samples stored at 75 %RH conditions.

Fig. 7 Taste scores in 9-point hedonic sensory evaluation of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) stored in different storage conditions at room temperature

Fig. 8 Color scores in 9-point hedonic sensory evaluation of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) stored in different storage conditions at room temperature

The chicken meat jerky stored at 33 %RH conditions could not consume because unacceptability of all attributes in sensory test which was in range of dislike moderately to extremely during day 15–30 of storage.

Conclusion

The chicken meat jerky prepared with mixed sugar (sucrose: fructose: sorbitol 70: 15: 15) had lower shear force value and TBA value than sample prepared with sucrose in initial of storage. Samples prepared with sucrose and mixed sugar stored in 33 %RH condition had the highest quality changes in textural and rancidity characteristics that were unacceptable in sensory evaluation after storage for 7 days. Shear force values of all samples stored at vacuum and 75 %RH condition were acceptable. All samples stored in vacuum condition could retard lipid oxidation during storage. Especially, sample prepared with mixed sugar kept in vacuum condition had the highest sensory score in overall acceptance attribute along the extended storage.

Fig. 9 Overall acceptance scores in 9-point hedonic sensory evaluation of chicken meat jerky prepared with 35 % sucrose or mixed sugar (sucrose: sorbitol: fructose 70: 15: 15; Mix) (by weight of meat) stored in different storage conditions at room temperature

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