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PHYSICO-CHEMICAL AND SENSORY QUALITY OF PEKIN DUCK JERKY SONICATED WITH COCONUT SHELL LIQUID SMOKE AND STORED FOR DIFFERENT PERIODS

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ABSTRACT: This study aimed to determine the effect of adding sonicated coconut shell liquid smoke to pekin duck jerky with different storage times at room temperature and vacuum packed. Ground duck jerky is made from Pekin duck meat (*Anas platyrhynchos domesticus*) soaked in coconut shell liquid smoke (CSLS) which has been sonicated for 20 minutes and seasoned with spices such as garlic, galangal, coriander, tamarind, salt, and coconut sugar. A laboratory experiment was done using a completely randomized design (CRD) consisting of 5 treatments (control: 0 day storage period, T1: 7 days, T2: 14 days, T3: 21 days, and T4: 28 days) and 4 replications. The results showed that the addition of sonicated CSLS with differences in the shelf life of pekin ground duck jerky had a significant effect ($P<0.01$) on pH, texture, color L, a*, b*, Aw, water content, fat, carbohydrates by difference, thiobarbituric acid (TBA), and iodine number. Had a significant effect ($P<0.05$) on ash content, and had no significant effect on Water Holding Capacity (WHC), protein content, and organoleptic quality. It was concluded that storing ground duck jerky for 14 days at room temperature and vacuum packed did not show any damage to pH, water activity, water content, fat, protein, TBA and iodine number, and did not occur rancidity.

Keywords: Liquid smoke, Jerky, Pekin duck, Shelf life, Sonication.

INTRODUCTION

The livestock sector in Indonesia needs to be developed more broadly to meet food needs and the community's nutritional needs. Duck is a type of poultry that fulfills animal protein because a fast growth rate supports it (Inayat et al., 2023). The Pekin duck (*Anas platyrhynchos domesticus*) is a bird species in the Anatidae family. Nutrient content such as high levels of water, protein, and fat can accelerate the process of decay in meat. Fresh meat that is not immediately processed will quickly rot due to infection and putrefaction by bacteria and fungi (Febrianta, 2022). The thick layer of fat in duck is found under the skin, making duck meat have thick skin. Duck meat has a high-fat content compared to other poultry, such as chicken and turkey. Poultry fat generally consists primarily of unsaturated fatty acids (Banaszak et al., 2020). Duck meat contains unsaturated fatty acids that reach more than 60% of the total fatty acids and is high in essential amino acids, which makes the oxidation process easier which can cause rancidity and reduce nutritional quality (Jin et al., 2021). Fresh duck meat is easily damaged if not processed immediately or given special handling and has a distinctive fishy smell. Therefore, preservation and processing of meat are carried out to prevent the decline in quality and nutrition and increase the taste consumers can accept. High fat in food affects sensory values such as increased textural and flavor qualities, but fat makes the food vulnerable to rancid smell. Duck meat not immediately processed will quickly become rancid due to oxidation. The oxidation process occurs due to damage by enzymes due to the presence of microbes in fat, thus affecting the shelf life and causing damage to sensory characteristics, which can reduce nutritional value.

Processing jerky is a food diversification to increase the taste that consumers can accept and improve quality. Jerky is a processed product of fresh meat added with spices and dried. The process of making jerky can be done by two methods, namely, the method of slice and grind. The drying method for making jerky can be done by drying with the help of sun heat and using an oven. The advantage of the sun heat method is that it is more economical but has the disadvantage that it takes a long time, depends on weather conditions, and sanitation is not maintained so that the quality of the jerky is not good. The advantage of using an oven is that the temperature can be adjusted, but it can result in case hardening, namely the condition of the outside (surface) of the jerky becoming dry while the inside is still wet (Kim et al., 2022). Ground jerky is a traditionally processed meat product made from ground beef added with coconut sugar, table salt, and spices, then printed into thin sheets with a thickness of approximately 3 mm and dried (Sorapukdee et al., 2016). Dried jerky is brown because of the maillard reaction, a non-enzymatic browning reaction between sugar and protein. The maillard reaction is a reaction that occurs between carbohydrates and primary amino acid groups, which produce a brown color in jerky (Dewi et al., 2020).

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Coconut shell liquid smoke can extend the storage period and improves sensory quality in color, texture, and jerky flavor. Liquid smoke has functional properties as an antioxidant, antibacterial and forms a distinctive color and taste. Liquid smoke can preserve food ingredients due to the presence of acid compounds, phenolic derivatives, and carbonyls (Himawati et al., 2018). Liquid smoke has antimicrobial properties and antioxidant compounds such as phenols and organic acids, so that it can be a safe preservative. The advantages of using liquid smoke are that it is easy to apply, fast, even product uniformity, produces good food characteristics, and is environmentally friendly. The component components of liquid smoke consist of the three most significant constituent compounds, namely acids which can affect the product's taste, pH, and shelf life. Carbonyl, which reacts with protein, will form a brown color in food, and phenol is the main constituent of aroma and shows antioxidant activity (Desvita et al., 2020).

The sonication method on CSLS is used to reduce the particle size of the liquid smoke to make it easier for compound components to absorb into duck meat during the soaking process so that more compound components are produced. The sonication method aims to reduce the sample particle size so that it can absorb more optimally. The non-thermal sonication method breaks down sample particles, enhances mass transfer, and homogenizes without harming molecular structures, while low temperatures prevent the loss of compounds with low boiling points (Franca-Oliveira et al., 2021). In addition, sonication or ultrasonic processes can reduce the sample size to nano size so that the texture of the sample is softer and smoother because the particle size is getting smaller (Agustini et al., 2021). The advantage of the sonication method is that it does not result in significant changes in the chemical structure of the particles and compounds of the raw materials used.

The addition of sonicated CSLS to the production of ground duck jerky has not been widely studied. Therefore, it is necessary to examine the effect of adding sonicated CSLS on the storage period of ground duck jerky in terms of physical, chemical, and organoleptic quality.

Ethical regulation of study

Research materials

a) The ingredients used to make jerky consisted of male pekin duck (*Anas platyrhynchos domesticus*) meat (breast, thigh, and wings) aged 50 days. Lubna brand coconut shell liquid smoke was purchased online for as much as 1.5%, while other ingredients used were table salt, coconut sugar, garlic, galangal, coriander, and tamarind.

b) Equipment for the production of duck jerky includes chopper Philips brand, knife, digital scale i2000 scale, label, glass mould, beaker glass, stirrer, dropper pipette, PE plastic (polyethylene), food dehydrator brand Tiross LT-06, ultrasonic processor brand Biomaisen model UCD-250, spoon, cutting board, slicer, machine, and plastic vacuum.

Research methods

A laboratory experimental method using a Completely Randomized Design (CRD) has been used. The study consisted of 5 treatments with a shelf life of control: 0 days, T1: 7 days, T2: 14 days, T3: 21 days, and T4: 28 days with each treatment consisting of 4 replications, so there were 20 experimental units.

Procedure for making ground duck jerky

Thoroughly wash the duck breast, thighs, and wings, then grind the meat until smooth. The ground meat is soaked for 30 minutes in liquid smoke with a concentration of 1.5% of distilled water which has been sonicated for 20 minutes, and then the meat is drained. After that, the meat is mashed and mixed thoroughly with spices such as garlic, galangal, coriander, tamarind, salt, and coconut sugar. The meat is printed with a glass mold measuring (20×18) cm with a thickness of 3 mm and placed on polyethylene plastic, then dried in a food dehydrator for 3 hours 15 minutes at 50^{0}C and turned every hour so that it dries evenly. Jerky was removed from the food dehydrator and cooled to room temperature. Jerky packaging was carried out in a vacuum and stored at room temperature for 0, 7, 14, 21, and 28 days.

Research analysis variables

Testing pH using a pH meter (Bishnoi et al., 2006). Water Holding Capacity (WHC) testing uses centrifugation (Chan et al., 2022). Texture testing uses a texture analyzer (Lis et al., 2021). L, a*, b* color testing using a color reader (Kulapichitr et al., 2022). Testing Water Activity (Aw) using an Aw meter (Husna et al., 2020). Testing for water, fat, and protein content uses the FOSS Food Scan method (Anderson and Collaborators:, 2007). Ash content testing and testing carbohydrate Levels by difference using the total carbohydrate method by difference (Yirmaga, 2013). Thiobarbituric acid (TBA) testing uses spectrophotometry (Zeb and Ullah, 2016). Testing iodine numbers using titrimetric (Rahmah et al., 2019). The organoleptic quality test used the descriptive test method using a score range of 1-5 and using 5 trained panelists and compared it with commercial beef jerky.

The organoleptic quality rating scale is: Color 5 = dark brown, 4 = brown, 3 = brownish red, 2 = red, and 1 = blackish brown. Texture 5 = very soft, 4 = soft, 3 = slightly soft, 2 = hard, and 1 = very hard. Aroma 5 = strongly smells of spices and smoke, 4 = smells of spices and smoke, 3 = slightly smells of spices and smoke, 2 = only smells of spices, and 1 = only smells of smoke. Taste 5 = strongly tastes meat and smoke, 4 = tastes meat and smoke, 3 = slightly tastes meat and smoke, 2 = only tastes meat, and 1 = only tastes smoke. Overall acceptance 5 = very acceptable, 4 = acceptable, 3 = somewhat acceptable, 2 = not accepted, and 1 = very not accepted.

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Data analysis

The data obtained in this study were analyzed using a variety of Analyses of Variance (ANOVA) using Complete Random Design (CRD). If the results obtained significantly or very significantly different data, then it was continued with Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

The average pH value, water holding capacity, and texture are shown in Table 1.

Table 1 – Average value pH, water holding capacity, and texture

Treatments	pH	Water holding capacity (%)	Texture (N)
Control	5.64 ± 0.04[a]	67.75 ± 3.86	7.69 ± 0.24[a]
T1	5.69 ± 0.03[a]	69.50 ± 2.89	8.39 ± 0.27[ab]
T2	5.75 ± 0.04[ab]	71.00 ± 4.24	9.22 ± 0.21[b]
T3	6.43 ± 0.05[b]	68.25 ± 3.10	9.47 ± 0.30[bc]
T4	6.54 ± 0.06[b]	65.50 ± 2.65	9.89 ± 0.18[bc]

[a,b,c,d:] Means different superscripts in the same column show a very significant effect (P<0.01). T1: storage period for 7 days, T2: 14 days, T3: 21 days, T4: 28 days

Effect of shelf life of ground duck jerky on pH value

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the pH value of ground duck jerky. Table 1 shows that the average pH value of ground duck jerky has increased with increasing storage time. The average pH value ranged from 5.64 to 6.54. The increase in pH value and the length of storage in ground duck jerky is due to the activity of microorganisms. Microbial activity is responsible for the rise in pH and prolonged storage of ground duck jerky (Fadlilah et al., 2020). The pH level significantly impacts the microbial population, with higher pH values promoting optimal microbial growth (Domínguez et al., 2022). During storage, bacteria can break down chemical compounds in meat, particularly proteins, into simpler compounds, leading to the production of substances like NH_3 and H_2S (Domínguez et al., 2022). The length of storage of jerky will be followed by an increase in pH due to the penetration of free water in the air. Penetration of free water from the air into the beef jerky makes the jerky moist and a suitable medium for the growth of bacteria. Based on the previous result, pH will increase with the more extended storage due to food undergoing chemical changes caused by a decrease in protein levels by microorganisms so that it can reduce the shelf-life of the resulting product (Amit et al., 2017). Proteolytic bacteria can enzymatically hydrolyze free amino acids, which cause an increase in the pH of food products. Foods with a pH close to neutral pH contain more numbers and types of bacteria. Microbial degradation of amino acids in meat leads to an increase in pH, as microbes utilize the remaining molecules as an energy source, resulting in elevated levels of NH_3 and H_2S (Diether and Willing, 2019).

The effect of ground duck jerky shelf life on water holding capacity

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had no significant effect (P>0.05) on the water holding capacity (WHC) of ground duck jerky. Table 1 showed that the average WHC value ranges from 65.50% to 71.00%. The lowest average is found on T5, or a storage period of 28 days, and the highest average is on T2, with a storage period of 14 days. The water holding capacity (WHC) of ground duck jerky decreased to 68.25% and 65.50% during the 21-day and 28-day shelf life, respectively. This decline can be attributed to microbial activity, which damages proteins and reduces their ability to bind to water. According to Domínguez et al. (2022), the reduction in WHC is a consequence of microbial activity during storage, leading to protein damage and a subsequent decrease in their water-binding capacity. Decreased protein levels in meat during storage can weaken the meat's ability to bind water so that the WHC value of the meat decreases. The decrease in water binding capacity is caused by the increasing amount of lactic acid, which results in many myofibril proteins being damaged, so that the protein's ability to bind with water becomes low. Phenolic compounds in liquid smoke can bind water by loosening the bonds of meat fibers so that some of the freely bound water will enter the inner space of the meat so that the WHC increases (Indiarto et al., 2019). The WHC value will affect the level of meat tenderness during processing. The higher the WHC value, the better the meat quality. The tenderness of jerky is related to consumer palatability. The high WHC value is caused by the high content of intramuscular fat that has not been oxidized and high protein content. High pH conditions can also cause an increase in the water holding capacity value.

Effect of shelf life of ground duck jerky on texture

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the texture value of ground duck jerky. Table 1 show that the average texture value of ground duck jerky ranges from 7.69 to 9.89 N. Ground duck jerky has a texture value that increases with the length of storage. Increasing the texture value of the ground duck jerky indicates that the

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texture of the jerky is getting harder during storage. The rise in the texture of ground duck jerky is associated with a reduced protein content in the product, as proteins have a lower capacity to bind water. This is consistent with a prior study that also indicated that protein content can impact the hardness of a product (Arandini et al., 2022). Products that are stored for a long time can reduce protein levels so that the protein's ability to bind water becomes low and will cause the product texture to become harder. Phenolic compounds in liquid smoke can form hydrogen bonds with water, thereby affecting the ability of meat to retain water. The WHC value will affect the tenderness, elasticity and texture of the meat. A low WHC value will make meat products tough. Changes in the tenderness of the jerky during storage are due to changes in the protein in the jerky, the higher the tenderness value, the harder the texture of the jerky.

The influence of the shelf life of ground duck jerky on color L, a*, b*

Data and color analysis results for lightness (L), redness (a*), and yellowness (b*) are presented in Table 2.

Table 2 – Average value of lightness (L), redness (a*), and yellowness (b*)

Treatments	Lightness (L)	Redness (a*)	Yellowness (b*)
Control	29.41 ± 0.10^{ab}	11.36 ± 0.54^{a}	4.80 ± 0.47^{a}
T1	29.39 ± 0.53^{a}	12.38 ± 0.85^{ab}	5.58 ± 0.49^{ab}
T2	30.90 ± 0.98^{bc}	15.93 ± 0.62^{b}	8.25 ± 0.26^{b}
T3	31.15 ± 0.62^{c}	17.11 ± 0.74^{bc}	8.44 ± 0.55^{bc}
T4	30.88 ± 0.26^{b}	18.09 ± 0.61^{c}	8.83 ± 0.22^{bc}

$^{a,b,c,d;}$ Means different superscripts in the same column show a very significant effect (P<0.01). T1: storage period for 7 days, T2: 14 days, T3: 21 days, T4: 28 days

Lightness (L)

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant (P<0.01) effect on the lightness (L) of ground duck jerky. Table 2 shows that the average lightness value (L) ranges from 29.39 to 31.15. Pekin duck jerky tended to increase lightness during storage, with the highest average lightness at 21 days and the lowest at 7 days. The lightness increase in ground duck jerky is due to the liquid smoke that can function as an antimicrobial and antioxidant to slow down microbial growth and inhibit fat oxidation which can affect the light color of the duck jerky. Meat that has decreased color during storage is due to fat oxidation. Adding liquid smoke to meat not only helps maintain the meat's color during storage but also acts as an antimicrobial agent, inhibiting fat oxidation (Akilie et al., 2021).

Lightness level of a product is indicated by the lightness (L) value using a colorimeter. The lightness level ranges from 0-100. The closer to 100, the lightness it is, while the closer to 0, the darker it is. Changes in the color of the meat during storage are caused by microbial growth in the meat, which can cause discoloration to darken, and the lightness of the meat can decrease. The color change is caused by a change or destruction of the meat pigment, namely myoglobin which is oxidized to brown metmyoglobin (Domínguez et al., 2022). The lightness of the jerky produced can be caused by coconut sugar, Maillard reaction, and sugar caramelization. The browning reaction in foods containing sugar can be accelerated by heating so that the reducing sugar component will form a brown compound (Montazeri et al., 2013). In the Maillard reaction or browning reaction, the carbonyl group of reducing sugar reacts with the amino group of meat protein and amino acids non-enzymatically to produce a dark brown color in meat (Kim et al., 2022).

Redness (a*)

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the redness (a*) of ground duck jerky. Table 2 shows that the average redness value (a*) ranges from 11.36 to 18.09. Duck jerky shows a redder color. The redness of duck jerky is affected by a non-enzymatic browning reaction. The presence of reducing sugars and heat-triggered proteins will result in a non-enzymatic browning reaction (Maillard reaction). One of the results of this reaction is the presence of a brownish-red product. The red hue of duck jerky is influenced by coconut sugar, imparting a caramelizing effect that results in a brownish-red color. The organic acid compounds in coconut shell liquid smoke contribute to the red color, while phenols and carbonyls are responsible for the brown coloration in the smoke product (Himawati et al., 2018).

Yellowness (b*)

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the yellowness (b*) of ground duck jerky. Table 2 shows that the average yellowness value (b*) ranges from 4.80 to 8.83. Yellowness color is produced due to a chemical reaction between phenol and oxygen and between protein and carbonyl in liquid smoke. The higher the oxygen, phenol, and carbonyl levels in liquid smoke, the more golden or brownish the color of the meat will be. The characteristic brownish-yellow color of smoked products is attributed to phenolic compounds present in liquid smoke, such as guaiacol, syringol, cresol, phenols, and ethers (Mathew et al., 2015). Montazeri et al. (2013) stated that the golden to brownish yellow color arises due to the interaction between phenol and oxygen, which produces a brownish

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yellow color on the surface of the food being smoked. The average values of water activity (Aw), water content, fat, protein, ash, carbohydrates by difference, TBA, and iodine number are shown in Table 3.

Table 3 – Average value of water activity, moisture content, fat, protein, ash, carbohydrate by difference, TBA., and iod number

Variables \ Treatments	Control	T1	T2	T3	T4
Water activity (Aw)	0.64 ± 0.04^{a}	0.68 ± 0.03^{ab}	0.71 ± 0.02^{ab}	0.74 ± 0.04^{b}	0.78 ± 0.02^{b}
Water content (%)	39.94 ± 0.43^{a}	42.77 ± 0.27^{b}	43.90 ± 0.98^{bc}	44.84 ± 0.43^{c}	47.06 ± 0.65^{d}
Fat level (%)	9.05 ± 0.42^{a}	10.09 ± 0.30^{b}	10.20 ± 0.20^{bc}	10.29 ± 0.47^{c}	10.72 ± 0.24^{c}
Protein level (%)	29.17 ± 0.22	29.24 ± 0.28	29.26 ± 0.50	29.13 ± 0.17	28.82 ± 0.41
Ash content (%)	0.39 ± 0.06^{bc}	0.41 ± 0.08^{c}	0.36 ± 0.05^{bc}	0.31 ± 0.02^{b}	0.26 ± 0.05^{a}
Carbohydrate by difference (%)	21.46 ± 0.18^{e}	17.49 ± 0.61^{d}	16.28 ± 0.74^{c}	15.44 ± 0.86^{b}	13.25 ± 0.44^{a}
TBA. (µM/g)	0.53 ± 0.06^{a}	0.56 ± 0.03^{ab}	0.59 ± 0.02^{b}	0.62 ± 0.02^{bc}	0.63 ± 0.02^{c}
Iodine number (g)	83.73 ± 2.59^{d}	79.87 ± 1.68^{c}	77.93 ± 2.01^{bc}	77.06 ± 1.40^{b}	76.95 ± 1.33^{a}

$^{a,b,c,d;}$ Means different in the same line show a very significant (P<0.01) effect on Aw, water content, fat, carbohydrates by difference, TBA, and iodine number, and have a significant (P<0.05) effect on ash content. T1: storage period for 7 days, T2: 14 days, T3: 21 days, T4: 28 days

Effect of shelf life of ground duck jerky on water activity (Aw)

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the water activity (Aw) of ground duck jerky. Table 3 shows that the average Aw ranges from 0.64 to 0.78. Ground duck jerky experienced an increase in Aw with longer storage time. The increase in Aw was related to the increase in water content in duck jerky, with increasing storage time and humidity during storage also affecting the Aw value of jerky. Humidity in the environment during the storage period at room temperature is related to the water content value. The higher the water content, the higher the water activity value (Aw). An increase in water activity (Aw) is associated with humidity, which represents an equilibrium relationship between the moisture content in the air (Meko et al., 2016). The high-water content will absorb water and vice versa to achieve equilibrium. The increase in Aw during storage was also caused by microorganisms' degradation of molecules in foodstuffs, namely by releasing bound water, which resulted in free water formation.

Water activity is directly linked to water content, meaning that a high-water content will elevate the water activity (Aw) and create favorable conditions for microbial growth (Pujaningsih et al., 2021). Food products with high Aw values are more prone to spoilage. The high Aw will make it easy for microbes to grow and cause food spoilage. The water activity in jerky products has considerable potential for contamination by microorganisms. A high Aw value will experience degradation caused by natural enzymatic or microbial damage. Water activity is closely tied to both water content and microbial proliferation. The rise in water activity (Aw) is a consequence of microorganism metabolism, leading to increased Aw levels in food products (Sharma et al., 2020). Factors like storage temperature, humidity in the storage area, and microbial activity contribute to this elevation in Aw values.

The effect of ground duck jerky shelf life on water content

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the water content of pekin duck ground jerky. Table 3 shows that the average water content of ground duck jerky ranges from 39.94% to 47.06%. The lowest average was found at 0 days of storage, and the highest average was at 28 days of storage. Jerky with a high-water content can make the jerky not last long because the high-water content can accelerate the damage to the duck jerky due to the presence of microbes in the product. The increase in water content in ground duck jerky during storage was due to the high humidity at room temperature, reaching 75%. The moisture content in meat had increased during room temperature storage, and the humidity influenced this in the surrounding environment during the room temperature storage period (Lekahena and Jamin, 2018). The humidity in the storage area affects the increase in moisture content because the product will absorb water from the surrounding air during storage at room temperature. High water content makes it easy for bacteria, mold, and yeast to multiply, which will cause changes in food ingredients (Pujaningsih et al., 2021). Increased water content was caused by air and water vapor entering the plastic vacuum packaging, so it increased during storage. If the humidity in the storage room is high, then the moisture content of the material can increase, and vice versa. The increase in water content is also due to ground duck jerky experiencing a decrease in quality caused by the oxidation of fat, which contains various unsaturated fatty acids and mineral content, which can accelerate fat oxidation. High water content can cause the product to be more easily damaged due to spoilage microbes that use water in the product as a growth medium (Arandini et al., 2022). High water content can cause microbes to multiply quickly, affecting product quality. Referring to the previous research, the breakdown of protein during storage into components such as ammonia and H_2S (hydrogen sulfide) can cause rancid odors and is followed by microorganism activity which causes the release of bound water to become free water, increasing water content (Budaraga et al., 2021). The increase in water content is influenced by humidity at room temperature because room temperature humidity can reach 86% (Alp and

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Bulantekin, 2021). Humidity at room temperature affects the increase in the resulting moisture content. The higher the humidity value, the more water vapor it contains, so the product's moisture content increases. High water content can cause the product to be damaged more quickly due to destructive microorganisms taking advantage of the water content contained in the product for their growth.

The effect of ground duck jerky shelf life on fat content

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect ($P<0.01$) on the fat content of ground duck jerky. The data in Table 3 shows that the average fat content of ground duck jerky ranges from 9.05% to 10.72%. The longer the storage, the fat content of the beef jerky increases. High levels of fat microorganisms cause them to multiply quickly and undergo oxidation, making the beef jerky turn rancid. The high fat content of duck jerky during storage is caused by increased water content which can reduce the quality of the jerky. A rapid increase in fat content can lead to the swift oxidation of food items, resulting in the development of an unpleasant rancid odor (Liu et al., 2023). As mentioned by Arandini et al. (2022), a high fat content creates favorable conditions for microbial growth. If stored for a long period of time, there is a risk of rancidity due to the increase in microorganisms, so the storage period is reduced. Meat that contains higher fat will produce a higher TBA value. This shows that the oxidation rate is influenced by the fat and fatty acid content. The breakdown of fat causes food to become rancid, thereby reducing its quality and nutritional value.

The effect of ground duck jerky shelf life on protein content

The results of analysis of variance showed that the difference in shelf life of ground duck jerky with room temperature storage and vacuum packaging did not have a significant effect ($P>0.05$) on the protein content of ground duck jerky. Data in Table 3 shows the average protein content of duck jerky ranges from 28.82% to 29.26%. The highest average was in T2 with a shelf life of 14 days, and the lowest was in T4 with a shelf life of 28 days. Storing duck jerky for 0 to 14 days experienced an increase in protein levels, this was due to the presence of phenolic compounds and organic acids in coconut shell liquid smoke which act as antioxidants and antibacterials so that they are able to inhibit pathogenic bacteria which can hydrolyze amino acids. Phenolic compounds have antimicrobial properties that can inhibit the growth of microbes in food. Ground duck jerky with a storage period of 21 to 28 days experienced a decrease in protein content because increasing water content would increase the number of microorganisms that could degrade the protein in the jerky. Arandini et al. (2014) stated that longer storage can cause a decrease in protein levels because the increasing number of microorganisms causes degradation of the protein contained in food. The growth of microorganisms causes a reduction in protein content because microorganisms require a source of nutrition for their growth, thereby causing a decrease in protein levels. The decrease in protein levels during storage is also caused by decomposition by proteolytic enzymes and the help of bacteria into carboxylic acids.

Effect of duck jerky shelf life on ash content

The analysis of variance showed that differences in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a significant effect ($P<0.05$) on the ash content. Table 3 shows that the average ranges from 0.26 to 0.41%. The longer the storage of ground duck jerky, the lower the ash content. The highest average ash content was in T1, with 7 days of storage, and the lowest average was in T4, with 28 days of storage. The ash content decreased during storage due to increased microorganisms with increasing water content in duck jerky. The ash content is related to minerals in food (Anggarani et al., 2019). The more minerals, the ash content in the food will increase. Extended room temperature food storage reduces ash content as microbes, reliant on minerals for growth and sustenance, consume these minerals over time (Arandini et al., 2022). During storage, there is an increase in Aw and water content, which microbial growth, bacteria, and mold will generally follow. Ash content is an inorganic substance left over from the combustion of organic material. Ash content is a mixture of inorganic or mineral components contained in a food. Foodstuffs comprise 96% organic matter and water; the remainder comprises mineral elements.

Effect of store period of ground duck jerky on carbohydrates by difference

The analysis of variance showed that the difference in the shelf life of ground duck jerky stored at room temperature and vacuum packed had a very significant effect ($P<0.01$) on the carbohydrate content difference in ground duck jerky. Table 3 shows that the average carbohydrate content ranges from 13.25% to 21.46%. Ground duck jerky experienced a decrease in carbohydrate content with increasing storage time. The elevated water content during storage influenced the chemical composition and quality of duck jerky, causing a decrease in carbohydrates. This decrease was attributed to chemical interactions that led to the formation of new compounds, ultimately impacting the overall food quality (Oessoe et al., 2014). Calculation of carbohydrates by difference is the determination of carbohydrates in foodstuffs roughly, and the results are usually listed in the list of ingredients. The decrease in carbohydrate content can be caused by an increase and decrease in other nutrient content, such as water, fat, protein, and ash, during storage because the carbohydrate content is highly dependent on the reduction factor. Carbohydrates in jerky are used to improve the texture of jerky to make it more tender. Carbohydrate content is needed as a binder and filler for jerky products, thus helping stability and increasing water absorption, making the texture soft in jerky (Chan et al., 2022). Carbohydrates have an essential role in determining the characteristics of food in taste, colour, and texture (Handayani et al., 2023).

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Effect of shelf life of ground duck jerky on thiobarbituric acid (TBA)

The results of the analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the levels of Thiobarbituric acid (TBA)/tranquillity of ground duck jerky. The data in Table 3 shows that the average TBA content of ground duck jerky ranges from 0.53 to 0.63 µM/g. Pekin duck jerky experienced an increase in TBA value every week. This indicated an increase in the rancidity of ground duck jerky. Ground duck jerky experienced increased TBA value due to increased fat content during storage, making it easier for jerky to undergo oxidation. Rahman et al. (2015) stated that increasing the fat content in food can potentially increase the fat oxidation rate, thereby affecting the value of thiobarbituric acid (TBA), and the food will cause rancidity (Liu et al., 2023). Meat that contains high fat will affect the increasing TBA value. This shows that the oxidation rate is affected by the fat and fatty acid content. Himawati et al. (2018) stated that liquid smoke is antioxidant and antibacterial and can preserve food ingredients due to the presence of phenol, carbamic, and carbonyl compounds. The results showed that the duck jerky had a slightly rancid smell on the 21st day or the 3rd week due to the higher TBA value of 0.62 µM/g. An increase in the TBA value causes a more pungent rancid odor and an increase in TBA during storage is caused by the breakdown of fat which causes a rancid smell and taste due to oxidation reactions (Liu et al., 2023).

Effect of shelf life of ground duck jerky on iodine number

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect (P<0.01) on the iodine number of ground duck jerky. The data in Table 3 shows that the mean value of ground duck jerky's iodine number ranges from 76.95 to 83.73 g, with the highest average being control which is 0 days of storage, and the lowest average being T4, which is 28 days of storage. Ground duck jerky during storage showed a decrease in iodine number. A decrease in iodine number indicates the development of rancidity in the product due to damage to the double bond by oxidation and the formation of secondary oxidation products during storage (Mahmud, 2023). The iodine number measures the amount of unsaturated fatty acids in fat. The decrease in iodine number is caused by the decomposition of fats and the saturation of double bonds through the degradation of hydroperoxides forming secondary products in the form of carboxylic acids, carbonyls, and other degradation products. The level of unsaturation will decrease because the double bond has been broken, so the iodine number decreases. A low iodine number indicates that not many unsaturated fatty acids are contained in the fat. These unsaturated fatty acids can bind to iodine and form unsaturated bonds. The number of bound iodine indicates the number of double bonds. The iodine number shows the number of iodine molecules that can form double bonds in fat, expressed in grams of iodine per 100 g of sample. The iodine number is used to determine the unsaturation and rancidity of a product. The higher the iodine number, the more advanced the rancidity process will occur in the product. Rancidity is damage or change in the smell and taste of a product. Unsaturated fatty acids can bind iodine and form saturated compounds. The amount of iodine bound indicates the number of double bonds contained in the product, the higher the iodine number, the better the quality of the product. The greater the iodine number, the more double bonds there are in the fatty acids of a product. A decrease in iodine number occurs when hydrogen molecules migrate to carbon, causing the fatty acid to become saturated. The double bonds of unsaturated fatty acids can bind oxygen to form peroxide which causes rancidity (Mahmud, 2023).

Effect of shelf life of ground duck jerky on organoleptic quality

Organoleptic testing was carried out by 5 trained panelists using a descriptive test. Organoleptic tests include colour, texture, aroma, taste, and overall acceptance. A descriptive scoring test assesses product intensity with increasing or decreasing order. The score used in the study ranged from 1 to 5, the higher the score given by the panelists, the higher the preference of the panelists for the product being tested, and vice versa. Testing the organoleptic quality of ground duck jerky using a comparison, namely commercial ground beef jerky. The average values for colour, texture, aroma, taste, and overall acceptance are in Table 4.

Table 4 – Average value of colour, texture, and overall acceptance of organoleptic quality

Treatments	Colour	Texture	Aroma	Taste	Overall acceptance
Control	4.15 ± 0.96	4.10 ± 1.29	4.30 ± 1.29	4.30 ± 0.58	4.40 ± 0.82^{d}
T1	4.10 ± 0.58	4.05 ± 1.50	4.15 ± 0.96	4.15 ± 0.50	4.20 ± 0.82^{cd}
T2	4.00 ± 0.82	3.50 ± 1.29	4.10 ± 1.29	4.20 ± 0.82	4.15 ± 0.96^{c}
T3	3.90 ± 0.58	3.70 ± 1.29	3.70 ± 1.29	3.80 ± 0.82	3.35 ± 0.50^{b}
T4	3.70 ± 0.58	3.45 ± 1.71	2.95 ± 0.96	3.10 ± 0.58	2.45 ± 0.50^{a}

$^{a,b,c,d;}$ Means different superscripts in the same column show a very significant effect (P<0.01). T1: storage period for 7 days, T2: 14 days, T3: 21 days, T4: 28 days

Effect of shelf life of ground duck jerky on organoleptic color

The analysis of variance showed that the difference in the shelf life of ground duck jerky when stored at room temperature and vacuum packed did not have a significant effect (P>0.05) on the color value of ground duck jerky based

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on organoleptic quality. The data in Table 4 shows that the average color score of ground duck jerky ranges from 3.70 to 4.15. The 0 to 14 days showed the brown duck jerky color criterion, and the shelf life of 21 and 28 days showed brownish-red jerky. The oxidation of proteins and fats causes color changes during shelf life. Commercial beef jerky, a comparison stored at freezer temperature, had the same color until the 28th day, namely brownish red. With the addition of liquid smoke, ground duck jerky can maintain its color due to the presence of phenolic compounds in the liquid smoke. Besides that, vacuum packaging can also preserve the color of the jerky. The brown color of beef jerky is produced due to the Maillard reaction during drying (Dewi et al., 2020). Compound components in CSLS, such as organic acids, carbonyls, and phenols, function to form a reddish brown color (Montazeri et al., 2013). The color of the jerky produced affects the consumers liking.

Effect of shelf life of ground duck jerky on organoleptic texture

The analysis of variance showed that the difference in the shelf life of ground duck jerky when stored at room temperature and vacuum packed did not have a significant effect (P>0.05) on the texture value of ground duck jerky based on organoleptic quality. The data in Table 4 shows that the average texture score of ground duck jerky ranges from 3.45 to 4.10. Ground duck jerky has the criteria for being soft with a shelf life of 0 to 7 days; on days 14 to 28 the beef jerky has a slightly soft texture. The texture of duck jerky does not change significantly during storage. This shows that liquid smoke is able to maintain the texture of ground duck jerky during the storage period. The commercial ground beef jerky used as a comparison material until the 28th day stored in the freezer had a soft texture. Phenolic compounds in liquid smoke can form hydrogen bonds with water, thereby affecting the binding capacity, elasticity and density of water.

The texture of duck jerky during storage is still acceptable because the beef jerky still has a relatively soft and chewy texture, the texture of the beef jerky is also influenced by the water content. The water content in duck jerky increases during storage so it doesn't change the texture of the jerky too much. The decrease in the texture of the jerky to become somewhat soft is due to the low protein value, so that the ability of the protein to bind water is reduced so that the WHC value of the jerky during storage decreases. The WHC value will affect tenderness. The texture will change along with changes in the water content of the food product (Akilie et al., 2021). Water content is one of the characteristics that greatly influences the appearance, texture and taste of a food product.

Effect of shelf life of ground duck jerky on organoleptic aroma

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had no significant effect (P>0.05) on the aroma value of ground duck jerky. Table 4 shows that the average value of duck jerky aroma ranges from 2.95 to 4.30. Jerky stored for 0 to 14 days has the criteria for smelling like spices and smoke. On the 21st day the beef jerky smelled slightly of spices and smoke, and the jerky smelled slightly rancid. On the 28th day the aroma of the jerky changed to just smelling of spices and smelled rancid. Commercial jerky during storage in the freezer until the 28th day is still acceptable because it does not smell rancid. The difference in the aroma of ground duck jerky and commercial jerky during storage is caused by differences in storage temperature. Ground duck jerky is stored at room temperature, making it easier for bacteria to grow. This may affect the sensory quality of the jerky. Aroma scores tend to decrease during product storage as a result of chemical component decomposition, resulting in an unpleasant rotten and rancid odor (Budaraga et al., 2021). The presence of enzymes and microorganisms causes deviations in the smell and aroma of the product. The foul smell occurs due to the activity of proteolytic bacteria which break down proteins into simple compounds such as polypeptides, amino acids, H_2S and the rancid smell is caused by lipolytic enzymes and protein breakdown.

Montazeri et al. (2014) stated that liquid smoke compounds such as guaiacol, eugenol, and syringol provide aroma to smoked products. Other components that also play a role in aroma and taste are p-cresol, o-cresol, guaiacol, 4-memethyguaiacol, 4-ethyl guaiacol, eugenol, 4-proppyguaiacol, and isoeugenol. Foodstuffs that contain high protein, when damaged by microbes, will produce a rancid odor. The stage of protein breakdown begins with the presence of microbes in a food ingredient, and proteins are broken down into small molecules in the form of free amino acids, dipeptides, and sugars. Microbes will use these small molecular food ingredients, and then the microbial population will overgrow along with the production of even smaller fraction compounds, such as cadaverine, putreceine, organic acids, CO_2, H_2S, and NH_3. Rancid odor in meat during storage occurs due to oxidation of unsaturated fatty acids and protein degradation. Rancidity is a process of lipid oxidation (Othón-Díaz et al., 2023). The smell of fat will change to an unpleasant odor and if the rancidity has reached its limit, it will taste bitter with longer storage time. The increasing growth of microorganisms can cause the aroma to become increasingly rancid and sour.

Effect of shelf life of ground duck jerky on organoleptic taste

The analysis of variance showed that differences in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had no significant effect (P>0.05) on the taste value of ground duck jerky. Table 4 shows that the average value of jerky flavor ranges from 3.10 to 4.30. Storage of duck jerky for 0 to 14 days has the criteria of meaty and smoked taste. Storage for 21 and 28 days of duck jerky has slightly tasted of meat and smoke. Storage for 21 days of duck jerky tastes slightly rancid, and commercial beef jerky during storage until 28 is still acceptable. Components in smoke that affect the taste of smoked products are phenols, carbonyls, and organic acids, and they function as antioxidants, which can inhibit the oxidation of protein and fats during storage so that the rate of

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decline in the flavor score can be hampered. The fat oxidation process in a product will affect the taste, color, texture and nutritional content of the product (Shahidi and Hossain, 2022). Changes in taste occur due to oxidation of unsaturated fats and fat decomposition. Phenolic compounds actively contribute to shaping the product's taste, enhancing its flavor, and promoting the presence of antioxidant components such as phenol aldehydes, 2,6-dimethoxyphenol, 2,6-dimethoxy phenolic acids, and 4-ethylphenol. Additionally, these compounds also play a key role in creating the taste and aroma of the final product (Montazeri et al., 2013). Components in smoke that affect the taste of smoked products are phenols, carbonyls, and organic acids, and they function as antioxidants, which can inhibit the oxidation of protein and fats during storage so that the rate of decline in the flavor score can be hampered.

Effect of ground duck jerky shelf life on overall acceptance

The analysis of variance showed that the difference in the shelf life of ground duck jerky by being stored at room temperature and vacuum packed had a very significant effect ($P<0.01$) on the overall acceptance value of ground duck jerky. Table 4 shows that the average overall acceptance score ranges from 2.45 to 4.40. Storage of ground duck jerky for 0 to 14 days has an acceptable overall acceptance value. Storage of jerky on the 21st day has a somewhat acceptable overall value because the jerky has started to smell and taste rancid. On the 28th day, ground duck jerky was not accepted because it was already flavorful and tasted rancid. Commercial beef jerky used as a comparison for up to 28 days of storage had overall acceptability that was still acceptable. This is due to the difference in storage temperature so that commercial ground beef jerky stored in the freezer can maintain its nutritional quality so that there are no deviations based on organoleptic quality, and ground duck jerky stored at room temperature shows an increase in water and fat content, which can reduce the nutritional quality so that it can affect other chemical components. The longer the storage, the lower the panelists' assessment of overall acceptability. This is caused by increasing levels of water, fat and rancidity, thereby reducing the acceptance of the aroma and taste of ground duck jerky, thereby reducing the overall product acceptance score.

CONCLUSION

The results showed that ground duck jerky stored at room temperature and vacuum packed had a very significant effect on pH, texture, color L, a*,b*, Aw, moisture content, fat, carbohydrates based on difference, TBA, and number iodine, significant effect on ash content, and no significant effect on WHC, protein content, and organoleptic quality. Pekin duck jerky with the addition of sonicated coconut shell liquid smoke and stored for different periods of time was able to survive until the 14th day because more than that the jerky experienced an increase in pH of 6.43-6.54; Aw of 0.74-0.78; water content of 44.84-47.06%; fat of 10.29-10.72%; TBA of 0.62-0.63 µM/g and decreased protein content by 29.13-28.82% and iodine number 77.06-76.95 g which can reduce the quality of duck jerky.

DECLARATIONS

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Authors' contribution

N. Salsabila research and developed, made samples, analyzed parameters, analyzed data, and compiled and revised the manuscript. A. Susilo and D. Rosyidi developed the research design, provided input, and directed and approved the final manuscript.

Conflict of interests

The authors have declared no conflict of interest.

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