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Effects of Edible Coating Treatment on Physicochemical, Sensory, and Microbial Properties to Prolong the Shelf Life of *Arenga pinnata* Fruit Dodol

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Abstract

Dodol, a chewy and sticky dessert, is a traditional sweet treat from Indonesia with regional variations across the country. Our study investigated the shelf life enhancement of *Arenga pinnata* fruit dodol produced by the Argo Sumilir group through various coating treatments. The dodol samples, stored at room temperature for 30 days, underwent treatments with sorbate and ginger. We evaluated the physicochemical, sensory, and microbial properties of these samples. The results indicated that the sorbate treatment notably extended the shelf life compared to other treatments. However, the final product exhibited a moisture content exceeding 20%, which is above the recommended limit for dodol. Sensory evaluation showed that, while panelists generally appreciated the product, some found it excessively sweet. Microstructure analysis revealed a smooth but uneven surface with cavities. Overall, *Arenga pinnata* fruit has potential for use in dodol, but additional refinement is necessary to enhance its shelf life and texture, and to achieve the standard moisture content requirements.

Keywords: *Arenga pinnata* fruit, Dodol, Indonesian Food, Microstructure analysis, Shelf Life

1. Introduction

Dodol is a well-known traditional delicacy in Indonesia, passed down through generations as an ancestral legacy. Each region in Indonesia boasts a distinctive variety of dodol, reflecting its local characteristics. Typically prepared using ingredients such as coconut milk, sugar, glutinous rice flour, or rice flour, dodol is cooked over a low flame for several hours. According to Syamsir and Sitanggang (2011), dodol production revolves around the mixing and heating of starch at high temperatures until it attains specific levels of water activity and moisture content. Extended cooking at low temperatures, as highlighted by Nasaruddin *et al.* (2012), contributes to the soft and compact texture of dodol.

Quality standards for glutinous rice dodol and related products are outlined in regulation by the National Standardization Agency of Indonesia (SNI 2986:2013). This regulation establishes thresholds for metal and bacterial contamination to uphold dodol quality. Internal factors such as raw materials also influence dodol quality and characteristics. Due to its amylopectin content, Glutinous ramparts were thickening and gelling properties

(Imanningsih, 2012). Sugar adds aroma and sweetness, serves as a preservative, and aids in texture formation (Gautara and Soesarsono, 2005). Additionally, coconut milk enhances the flavor profile of dodol (Nuroso, 2013).

Arenga pinnata fruit, derived from palm tree, is characterized by its thin yellow skin, soft texture, and slightly transparent, chewy white seed core. According to Purwati and Nugrahini (2018), *Arenga pinnata* fruit contains various nutrients, including energy, protein, fat, carbohydrates, fiber, calcium, phosphorus, and iron. The majority of the population in Indonesia traditionally use it to produce 'kolang-kaling,' a popular ingredient in beverages. However, the market value of 'kolang-kaling' as a beverage ingredient remains relatively low due to its short shelf life. However, challenges persist, notably the short shelf life of *Arenga pinnata* fruit dodol, resulting in mold growth.

Edible coatings serve as carriers for preservatives such as antimicrobial or antioxidant additives. These coatings require both mechanical strength and hydrophobic properties to reduce the permeability to oxygen and water vapor, thus regulating the fruit's respiration rate and maintaining its firmness. Moreover, they should demonstrate biocompatibility, biodegradability, antibacterial, and antifungal characteristics, while also forming a membrane (Fernández-Pan *et al.*, 2011). Sorbic acid, a commonly used preservative in various foods like non-alcoholic beverages, grape juice, dried fruits, and fruit and vegetable preparations, has been utilized as a model additive in migration studies. Previous research has shown the potential of different edible materials applied to high moisture model foods to retain and control the diffusion of sorbic acid (Guillard, 2009).

This study aims to prolong the shelf life and assess the characteristics of *Arenga pinnata* fruit dodol produced by the Argo Sumilir group. *Arenga pinnata* fruit dodol was stored for 30 days at room temperature, with physical, microbial and chemical analyses conducted every five days. Proximate analysis, sensory evaluation, and morphological assessment of *Arenga pinnata* fruit dodol with optimal storage quality were performed on the selected final product.

2. Methodology

2.1 Preparation of Dodol

The *Arenga pinnata* fruit dodol mixture prepared consists of three types: original dodol (O), dodol with the addition of 5% (w/w) ginger powder (G), and dodol with the addition of 0,025% (w/w) potassium sorbate (S). The *Arenga pinnata* fruits were washed, drained, combined with salt, and allowed to stand for 8 hours before being rinsed again until clean. Subsequently, it was mashed using a chopper to produce *Arenga pinnata* fruits paste. The preparation of dodol commenced with a caramelization process, wherein coconut milk, granulated sugar, and palm sugar were combined and cooked in a hot pan, stirred until boiling. Following boiling, glutinous rice flour and rice flour were added until homogeneous and free of lumps. The *Arenga pinnata* fruits paste was then mixed into the mixture and continuously stirred over low heat until the mixture reached a thick consistency. The addition of ginger powder and potassium sorbate as treatments to the mixture was added at this final step.

After the mixture reached a thick consistency, it was cooled down and cut. Then, each of the O, G, and S mixtures was divided into two portions, where one portion was directly packaged, and the second portion was treated with a coating solution by evenly spreading it. The coating solution preparation was based on the study conducted by Pramsiska *et al.* (2020) with modifications. Pectin 2% (w/v) was dissolved in distilled water and heated until the gelatinization temperature was reached. Glycerol and potassium sorbate 0.025% (w/v) were added and homogenized for 30 minutes. The coating solution was then cooled and ready for application.

2.2 Physicochemical Parameters

The prepared dodol is stored for 30-days period and subjected to several parameter tests. The palm sugar dodol product stored at room temperature consists of six treatments: Original Non Coating (ONC), Ginger Non Coating (GNC), Sorbate Non Coating (SNC), Original Coating (OC), Ginger Coating (GC), and Sorbate Coating (SC). The parameters tested include moisture content, water activity, proximate, and textural properties.

- **Moisture Content and Water Activity** (AOAC, 2006)

Moisture content was determined according to AOAC 931.04 method. Sample 2 g was taken and kept in a hot air oven for 3 h at 105 °C. Water activity was determined using Aw meter (Aqua Lab Series 3 Water Activity Meter). Moisture content was recorded as percentage (%) and calculated using the formula in Figure 1.

$$Moisture\ Content\ (\%) = \frac{\mathrm{W1} - W2}{W}\ x\ 100\%$$

W1 = The weight of cup and the sample before drying
W2 = The weight of cup and the sample after drying
W = The weight of sample

Figure 1. The Formula of Moisture Content

- **Proximate**

The tested characteristics of *Arenga pinnata* fruit dodol involved one sample treated optimally during one-month storage. The proximate composition of the product was analyzed according to the AOAC procedure (AOAC international, 2012). Ash content was determined by ashing 2 grams of samples using a furnace (Nabertherm Logotherm preheater S17, Germany) at room temperature. temperature 550 ^{0}C for 6 hours. Fat content was determined by dry samples extracted using 300 mL n-hexane with a soxlet unit for 4 hours and dried with a rotary evaporator. Crude fiber was analyzed by the AOAC procedure (method 962.09) (Horwitz, 2000). Crude protein content was tested using the Kjeldahl method and a conversion factor of 6.25 to determine the % of total nitrogen and carbohydrates determined using by difference analysis. All results are reported as the mean ± standard deviation of duplicate analyses.

- **Textural Properties** (Mirazimi *et al.,* 2022).

The textural properties of dodol were evaluated using a Texture Profile Analysis (TPA) test. Dodol samples were analyzed at 25°C employing a Texture Analyser (TA-XT plus, Stable Micro Systems, UK) equipped with a compression plate (P/75). The TPA involved double-cycle compression tests conducted at a test speed of 2 mm/s, a post-test speed of 10 mm/s, and a compression strain set at 75%, with a trigger force of 20 g. Each formulation underwent three measurements per sample. Parameters such as hardness, cohesiveness, adhesiveness, and gumminess were recorded based on one replicate per sample. The data analysis was conducted using one-way ANOVA (analysis of variance) in the SPSS program, followed by Duncan's test.

- **Scanning Electron Microscope (SEM)**

The electron structure of the morphology of *Arenga pinnata* fruits dodol observed using a scanning electron microscope (SEM). FESEM observation of the morphology of the *Arenga pinnata* fruit was conducted using a JEOL JIB 4610F FE-SEM model. The samples were placed on the FESEM sample stub, and the specimen was coated with carbon followed by gold.

2.3 Microbial Parameters

- **Total Plate Count Method** (Mirazimi *et al.,* 2022).

Total Plate Count method (cfu/ml) was performed every five days during the 30-days storage period. Dodol was measured by weighing about 5 gr, added with 45 ml of sterile NaCl and homogenized in a stomacher for one minute. Pipe 1 ml of each dilution to petri-dish, then poured 15-20 ml Plate Count Agar (PCA) media at 40°C. After the media solidified, the petri-dish was incubated for 48 hours at 35-37°C. The number of colonies was determined using a colony counter.

2.4 Sensory Parameters

- **Organoleptic**

The hedonic test was carried out by giving each panellist one *Arenga pinnata* fruit dodol to test. Untrained panellists of 40 adults' people, men, and women were asked to evaluate product in 5 parameters: color, taste, aroma, texture, and overall acceptance. Consumer acceptability scores on a 9-point hedonic scale (Scale: 1-dislike extremely; 2-dislike very much; 3-dislike moderately; 4-dislike slightly; 5-neutral; 6-like slightly; 7-like moderately; 8-like very much; 9-like extremely). Result was reported as mean ± standard deviation and displayed in the form of a spider web and visually represented in the form of a spider web, allowing for a comprehensive visualization of the product's acceptability across multiple attributes.

3. Result and Discussion

3.1. Ethnic Aspect of *Arenga pinnata* Fruit Dodol

Dodol, a traditional food renowned in Southeast Asia, is characterized by its chewy, sticky texture and sweet taste. Typically, the main ingredients for making dodol consist of glutinous rice flour, coconut milk, white sugar, and palm sugar (Seow *et al.*, 2021). Dodol is also closely associated with Malay culture. The Malay Archipelago refers to the islands stretching between the Indochina and Australia mainland. This region encompasses Southern Thailand, the Malay Peninsula, Java, Madura, Sunda, Borneo, Sulawesi, the Philippines, and the Islands in Eastern Indonesia (Marzali, 2012). Hence, it is reasonable to find dodol in these areas.

Dodol or *jenang* used as offerings through generations may include *jenang abang, jenang abang putih,* and *jenang procot* (Baehaqie, 2014). The various types of dodol signify its existence since ancient times and its inseparable part of the *Orang Kalang's* traditions in Kendal Regency. The fusion of dodol culinary culture long prevalent in Kendal Regency, with the untapped potential of local agriculture, mainly the *Arenga pinnata* fruit, could position dodol kolang-kaling as a signature dish of Kendal Regency with potential for further development (Figure 2).

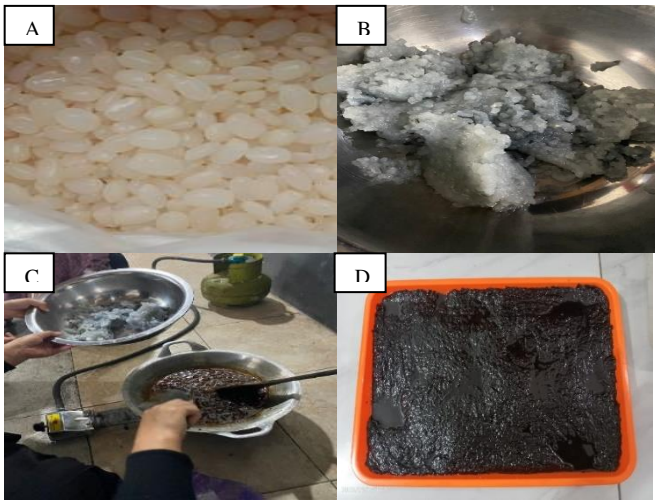


Figure 2. A Raw *Arenga pinnata* fruit from Indonesia. **B** Mashed Raw *Arenga pinnata* fruit. **C** Production of *Arenga pinnata* fruit dodol. **D** Processed *Arenga pinnata* fruit dodol

3.2 Physicochemical Parameters

- Water Activity

Based on the Table 1, the obtained samples of *Arenga pinnata* fruit dodol exhibited a range of water activity (Aw) from 0.7 - 0.84. This is in line with the statement of Hanggara *et al.* (2016) and Barbosa-Cánovas (2020) state that the activity of dodol water is relatively low, about 0.5 - 0.84, so it can inhibit microbial growth and relatively resistant to storage. The ingredients for making dodol are mixed with salt and/or sugar, as well as additional ingredients (such as ginger and potassium sorbate) and then processed, such as cooking, can affect the activity of the water contained in the dodol. Water activity (Aw) refers to the amount of free water in foods. When food is contaminated with microorganisms, water activity is a significant factor. Water must be added or removed to alter food's Aw in order to preserve and regulate food quality. A margin of safety is provided by additional barriers against the growth of certain bacterial species and spoiling by aw-resistant microorganisms (mostly molds and yeasts, which can grow at as low as 0.61 aw). To achieve these aims, chemical preservatives such as nitrites, sorbates, sulfites, benzoates, natural antimicrobials, and smoke components are commonly used (Tapia *et al.*, 2020; Fellows, 2022).

Table 1. Water Activity during Storage Period

Samples	Days					
	5	10	15	20	25	30
ONC	0.827	0.813	0.787	0.787	0.806	0.827
OC	0.804	0.811	0.788	0.793	0.798	0.804
SNC	0.760	0.765	0.737	0.745	0.763	0.777
SC	0.779	0.775	0.750	0.746	0.761	0.772
GNC	0.846	0.838	0.806	0.803	0.830	0.828
GC	0.843	0.824	0.807	0.805	0.828	0.832

- **Moisture content**

Knowledge regarding food's moisture content is crucial since it affects how the product's chemical and physical characteristics change. Moisture content is a substance that displays the amount of water per unit weight. Analysis of variance (ANOVA) results demonstrated that, throughout the duration of the 30-day storage, all dodol samples (OC, ONC, SC, SNC, GC, and GNC) had a significant impact on moisture content, with a range of 20.78–31.73% (Table 2). Further analysis using the 5% Tukey Test (HSD) revealed no significant difference in the moisture content of Original Coating (OC), Original Non-Coating (ONC), Sorbate Non-Coating (SNC), and Sorbate Coating (SC). In contrast, Ginger Dodol Non-Coating (GC) and Ginger Coating (GC) were significantly different from Original Coating (OC), Original Non-Coating (ONC), Sorbate Coating (SC), and Sorbate Non-Coating (SNC). Overall, the moisture content of every sample was more than 20%. However, the result meets the quality requirements for the moisture content of semi-solid food (intermediate moisture foods) ranging from 10% to 40% and can be consumed without rehydration (Hanggara *et al.*, 2016; Guidance, 2018).

Since the commencement of storage, the moisture content of the samples has been more than 20%, which can be attributed to the high moisture content of the palm fruit, which is used in the form of pieces of fruit rather than dried fruit or flour. *Arenga pinnata* fruit raw material analysis result showed that the moisture content was 93.80%. One of the factors affecting dodol moisture content is determined by its galactomannan content. Galactomannan is a hydrocolloid substance found in *Arenga pinnata* fruit that contributes to dietary fiber. This dietary fiber that dissolves in water has the capacity to bind water and create a gel. This gel-forming property allows the palm fruit to retain water during the dodol processing process (Sari *et al.*, 2020).

Table 2. The Moisture Content During Storage Period

Samples	Storage Period (Days)					
	5	**10**	**15**	**20**	**25**	**30**
ONC	25.39%	25.54%	24.67%	28.38%	26.17%	27.74%
OC	25.58%	25.83%	26.18%	31.26%	24.95%	27.43%
SNC	20.78%	21.73%	20.72%	25.41%	21.09%	21.67%
SC	22.34%	19.84%	21.38%	25.82%	21.73%	22.86%
GNC	28.20%	27.91%	29.10%	31.64%	28.63%	30.34%
GC	28.71%	29.42%	27.54%	31.73%	30.68%	29.82%

- **Texture Profile Analysis (TPA)**

The Texture Profile Analysis (TPA), which simulates human chewing action, is an important technique for describing texture. It entails a two-bite compression test to link textural characteristics and mechanical qualities during oral processing (Chen, 2009). The results of the TPA applied to the SPF Dodol samples are shown in Table 4 which offers information about their textural characteristics. The highest positive and negative height values of the initial peak indicate hardness and adhesiveness, respectively. Dodol tends to stick slightly to the teeth, which can be desirable in certain contexts. One might envision that a high-quality dodol is one that resists breaking apart when in the mouth and is easy to chew with a tooth (Seow *et al.*, 2021).

Table 4. Textural Properties of *Arenga pinnata* Fruit Dodol

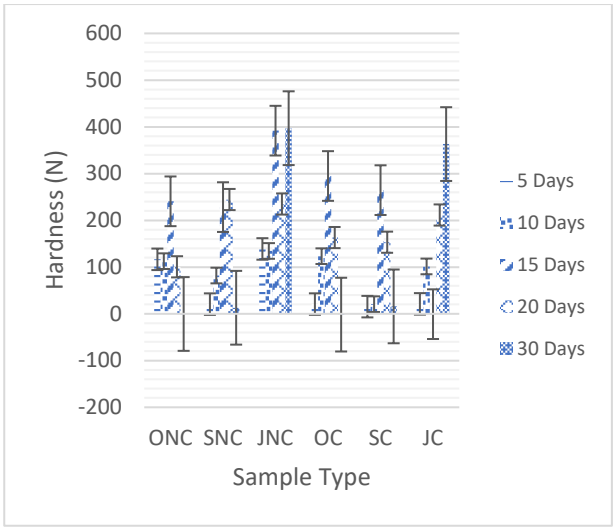
Samples	Hardness (N)	Adhesiveness (N.s)	Cohesiveness (-)	Gumminess (N)
GC	122.30±160.05[a]	-1369.73±1527.41[bc]	0.0031±0.0007[a]	37.66±48.76 [a]
GNC	234.64±157.57[a]	-1334.71±1288.23[bc]	0.0029±0.0004 [a]	63.30±60.74 [a]
SC	89.50±103.79 [a]	-2751.12±484.44[a]	0.0031±0.0001 [a]	30.17±35.23 [a]
SNC	107.99±124.33[a]	-2615.84±664.25[ab]	0.0032±0.0004 [a]	32.85±36.63 [a]
OC	98.42±128.21[a]	-1527.52±732.67[abc]	0.0031±0.0001 [a]	36.36±45.12 [a]
ONC	76.63±99.46[a]	-1193.43±411.21[c]	0.0031±0.0002 [a]	36.14±43.36 [a]

Note: Different superscript letters in the same coloumn indicate a significant difference (p<0.05)

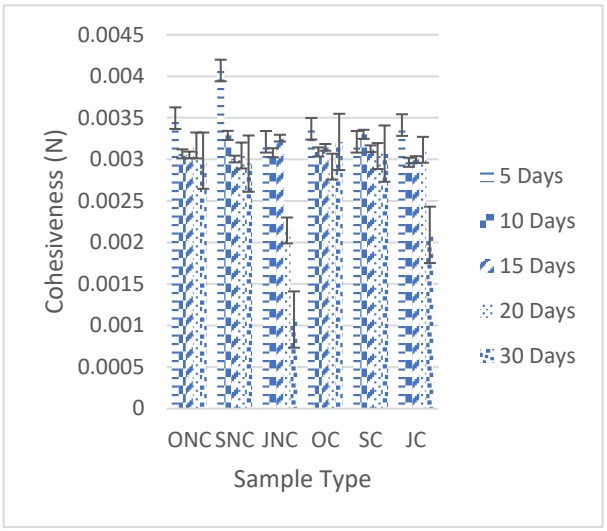
According to the TPA (Texture Profile Analysis) results, the SPF (*Arenga pinnata* fruit) of dodol was stored for 30 days with testing intervals every 5 days, with treatments differentiated by dodol coating and non-coating, as well as variations in dodol ingredients. There were no significant differences ($p < 0.05$) in the hardness, cohesiveness, and gumminess of different ingredient variants, even after coating or non-coating treatments. Adhesiveness was the sole metric that varied in this test. ONC and JNC had the lowest values -1193 N·s and -3.73 N·s, respectively, while SC, SNC, and JC had the highest measurements -2751.12 N·s, -2615 N·s, and -1369.73 N·s, respectively. The presence of starch chains with low molecular weight in the dodol formulation reduces the degradation of other starch molecules, thus increasing product adhesiveness (Chuang and Yeh, 2006). Hardness can be defined as the highest pressure point during the first bite. Table 4 shows that the addition of ginger tends to result in higher hardness values, namely GC 122.30 N and GNC 234.64 N, while the original samples showed lower values compared to the sorbate samples. According to Altamimi *et al.* (2020) research, incorporating low concentrations of ginger into powdered apple juice beverages does not affect the sensory quality of the product.

Cohesiveness is defined as the degree to which a substance is mechanically broken down. Products with high cohesiveness have structural integrity that can withstand compressive or tensile stresses (Seow *et al.*, 2021). Additionally, cohesiveness can serve as an indicator to measure the level of difficulty in breaking down the internal gel structure (Lau *et al.*, 2000). The average dodol samples showed no significant differences; low significant values indicate that the product is more prone to deformation or requires less energy to be broken down, due to the slowest retrogradation resulting in the weakest gel structure (Seow *et al.*, 2021).

Gumminess is defined as the product of multiplying the hardness value by the cohesiveness value, and it represents a characteristic of semi-solid food items with low hardness but high cohesiveness. Notably, the gumminess data for GC, SC, SNC, OC, and ONC are 37.66, 30.17, 32.85, 36.36, and 36.15, respectively. The gumminess data for GNC indicates a value twice as high as the other five samples. This aligns with the parameter of hardness, where GNC obtained the highest value. This data is consistent with the findings of Kreungngern and Chaikham (2016), who stated that the higher the hardness value, the higher the gumminess. The energy required to crush semi-solid food products until they are ready to be swallowed increases significantly when the resulting dodol has a higher hardness value.



(a)



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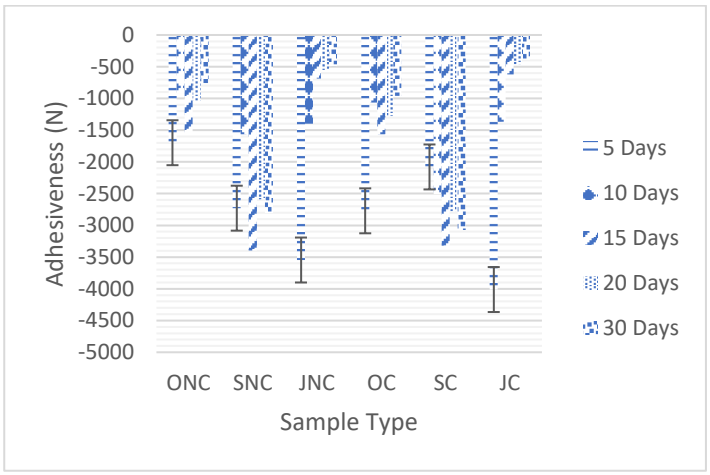

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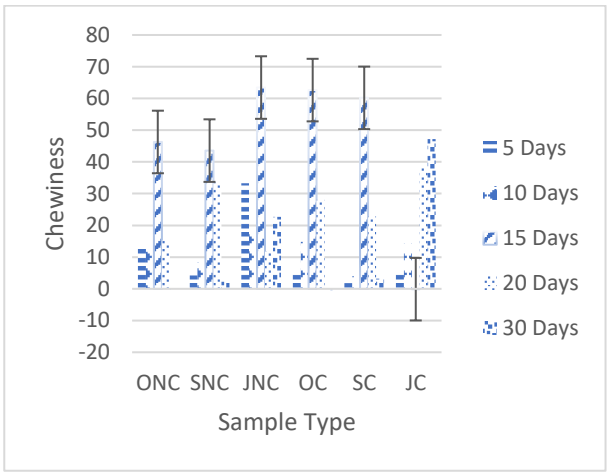

(d)

Figure 3. Texture Profile Analysis of *Arenga pinnata* Fruit Dodol

As depicted in Figure 3, during the one-month storage period, it is evident that GNC has the highest average hardness parameter compared to the other five samples, although it experiences fluctuations between days 5 and 30. Based on the time variable, ONC, SNC, OC, and SC samples exhibit a decrease in hardness, while GC shows an increase. The highest value recorded on day 5 is for GNC at 138.813 N, while the lowest is for SC at 15.35 N. The majority of samples experience an increase in hardness of up to 50% on day 15, followed by a decline by day 30. This trend becomes evident when comparing the coatings of Ginger and Sorbate. Moreover, in the non-coated sorbate sample, hardness was notably affected by the duration of application. The decrease in hardness in sugar-starch-based food products can be attributed to the exclusion of water molecules from the amorphous phase when sugar molecules crystallize again, also known as free water.

The observed trend in elasticity can be understood as the energy required to transform semi-solid food into a ready state (Szycesniak, 2002). Adhesiveness of the samples is observed to increase with growth and expansion. In terms of adhesiveness parameter, it is observed that starting from day 5 of observation, the composition of dodol with treatment coatings and non-coatings with the addition of ginger provides high adhesiveness values followed by a decrease over time in storage. This can be seen in Table 4 with samples GNC and GC. In contrast,

the addition of sorbate (SC and SNC) and the original (OC and ONC) experience texture instability in terms of the adhesiveness parameter. Thus, it can be concluded that ginger has an effect on the adhesiveness value of the product. The inclusion of ginger in starch-based dodol appears to be more effective in inhibiting it.

In terms of the cohesion parameter, based on the storage time variable, the majority experience consistency in changes that are not very significant. Particularly on day 15, but on day 30, the cohesion of each sample experiences a decrease and tends to be weak. The highest cohesion value is found in sample SNC, reaching 0.003 on day 5, and the lowest value is 0.0010 on day 30 for sample GNC. With high glutinous rice contents, dodol has a large amount of amylopectin of about 98% of total starch, which results in high cohesiveness at variance sorbat coating. Cohesiveness refers to the work of cohesion, and the more negative the value, the more "cohesive" the sample. The highest consistency among the tested formulations is for all samples, which do not differ significantly when adding ginger and sorbate or with coating and non-coating treatments. GC exhibits weak consistency and cohesion, indicating less resistance to flow. Considering the results of the texture profile analysis correlate with the total plate count, water activity, and moisture content, the selected formula to proceed with product characteristic testing was *Arenga pinnata* fruit dodol with non-coating sorbate (SNC).

- **Proximate**

Results of the chemical analysis of the product, encompassing moisture content, ash content, protein content, fat content, crude fiber, and carbohydrates by difference. According to the results, the moisture content and ash content of *Arenga pinnata* fruit dodol conform to the stipulated maximum requirements in SNI 2013, namely, 20% and 1.5% (BSNI, 2013). The moisture content influenced to microbiological activity and the shelf life of products. A contributing factor to the sustained high-moisture content is the insufficient duration of the cooking process, leading to inadequate water evaporation. Ash content is associated with the mineral composition derived from the raw materials used.The raw materials exhibit relatively small ash content, such as *Arenga pinnata* fruit (0.08%), coconut milk (0.7%), sugar palm (2%), sugar (0.07%), glutinous rice flour (0.74%), and rice flour (0.6%) (Khotimah *et al.*, 2018; Abdullah *et al.*, 2022; Mustafa *et al.*, 2020 Setyawati *et al.*, 2016).

Table 5. Proximate composition of *Arenga pinnata* fruit dodol

Proximate composition	%
Moisture content	20.26 ± 0.16
Ash content	0.02 ± 0.00
Protein	0.04 ± 0.00
Fat	4.79 ± 0.06
Carbohydrate[1]	74.89 ± 0.21
Crude fiber	2.29 ± 0.21

Mean ± SD of duplicate analysis

[1] Carbohydate was calculated as by difference of wet weight basis.

Arenga pinnata fruit dodol has the highest carbohydrate content (74.89%) and water (20.26%), while the fat, protein and ash content are relatively low. In accordance with Khotimah *et al.* (2018), *Arenga pinnata* fruit contains 4.83% carbohydrates, mainly consisting of galactomannan, which consists of mannose and galactose. (Khotimah *et al.*, 2018). The main ingredient of has a low-fat content (0.04%), while additional sources of fat can come from coconut milk (15%), glutinous rice flour (5.2%), and rice flour (6.67%). The decrease in crude fiber

content (2.29%) was caused by the low fiber content in *Arenga pinnata* fruit and other raw materials, such as glutinous rice flour and rice flour, whose fiber content ranges from 2.01% - 2.4% (Setyawati *et al.*, 2016).

- **Microstructure of *Arenga pinnata* fruit dodol**

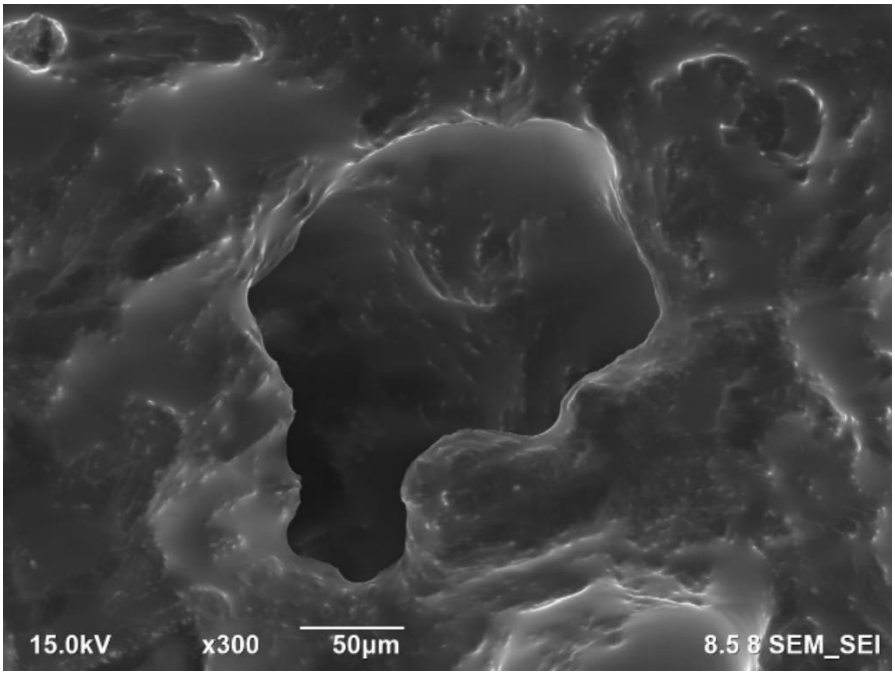

Figure 5. SEM Morphological Image of *Arenga pinnata* Fruit Dodol

The cross-sectional surface image of dried *Arenga pinnata* fruit dodol using a dehydrator could be observed in Figure 5**.** The microstructure of this dodol was examined at 300 times magnification. It was evident from the image that the structure of dodol was smooth but uneven, with cavities at certain points. A new complex network structure was likely formed as a result of the interaction between starch and protein, after the incorporation of other ingredients in the dodol cooking process (Qiu *et al.*, 2015). This was also in line with the findings of Seow *et al.*, (2021), stating that a new complex network structure was likely formed as a result of the interaction between starch and protein, after the incorporation of other ingredients in the dodol cooking process.

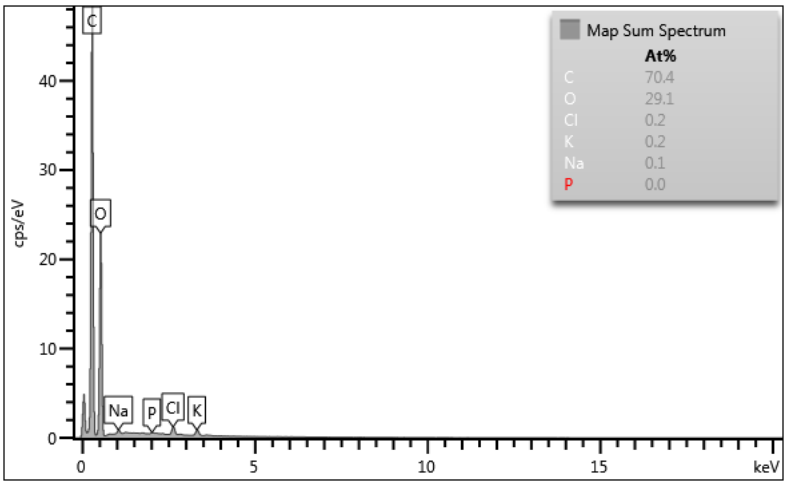

Figure 6. Energy Dispersive X-Ray (EDX) Result of *Arenga pinnata* Fruit Dodol

SEM was a microstructural test conducted to analyze the shape and surface of particles in the sample. Scanning Electron Microscopy (SEM) was an electron microscope with high magnification capabilities that could image surfaces on materials (Kustomo, 2020). Based on the scanning electron microscopy (SEM) recordings of the dodol microstructure, quantitative analysis of the constituent components of the dodol surface in terms of the percentage of each atomic element was obtained. According to Figure 6, it was found that the most abundant atoms were C 70.4%, O 29.1%, Cl 0.2%, K 0.2%, and Na 0.1%. The prevailing atomic elements are the components of fat, which include a carbon atom (C) and an oxygen atom (O) (Tharukliling *et al.*, 2021). The fat originated from coconut milk added as one of the main ingredients in making *Arenga pinnata* fruit dodol. The results of the SEM recordings on the microstructure became supporting data for sensory quality, especially on the texture as the SEM-EDX results could provide an overview of how surface topography and texture relate to the hardness of dodol.

3.3 Microbial Parameters

- **Total Plate Count (TPC)**

A food product has a minimum limit of microbial contamination, hence the amount of microorganisms in it must be known. Numerous microorganisms are analyzed to identify consumer dangers and product quality indicators. To ensure that the product is both marketable and safe for consumption, the parameter such as total plate count (TPC) was utilized in the initial stage of the product quality analysis to identify microbial contamination. The TPC results for samples stored for 30 days were shown in Table 3**.** The number of colonies increased from day 5 to day 30 according to the TPC results. On the fifth day, TPC showed that SNC sample had 3.25 x 10^2 CFU/g of colonies; 2.11 x 10^3 CFU/g (OC); 2.30 x 10^3 CFU/g (ONC); 1.31 x 10^4 CFU/g (SC); 1.26 x 10^5 CFU/g (GC); and 2.36 x 10^5 CFU/g (GNC). The number of colonies increased the next 5 days while the samples were being stored. Microbial growth may be influenced by the food's nutritional content. Aside from water, bacteria need a minimum of nutrients: a carbon source, a nitrogen source and some mineral salts for energy to thrive (Bonnet *et al.*, 2020). Thus, Dodol can be an excellent growth medium that is rich in the nutrients needed by microorganisms to flourish.

GNC and GC samples were significantly different from SNC, SC, OC, and ONC. As of day 30, the number of colonies remained below the maximum number stipulated by the regulation in Indonesia. According to Indonesian Food and Drug Authority, that food is clasified to be in good condition and acceptable when the number of microbial contamination is below 10^4 and 10^5 CFU/g is the maximum amount of microbiological contamination allowed in dodol made with glutinous rice flour and fruit (ISO 4833-1) (Indonesian FDA, 2019). Based on the reference, *Arenga pinnata* fruit dodol with several treatments (OC, ONC, SC, SNC, GC, and GNC) were categorized in safe and acceptable food.

Table 3. Total Plate Count During Storage Period

Samples	Storage Period (Days)					
	5	**10**	**15**	**20**	**25**	**30**
ONC	2.30×10^3	3.57×10^3	4.48×10^3	5.14×10^3	5.64×10^3	6.05×10^3
OC	2.11×10^3	1.89×10^4	3.38×10^4	4.44×10^4	5.27×10^4	5.94×10^4
SNC	3.25×10^2	1.45×10^3	2.28×10^3	2.88×10^3	3.34×10^3	3.71×10^3
SC	1.31×10^4	1.77×10^4	2.04×10^4	2.23×10^4	2.38×10^4	2.51×10^4
GNC	2.36×10^5	3.68×10^5	4.86×10^5	5.69×10^5	6.34×10^5	6.87×10^5
GC	1.26×10^5	1.81×10^5	2.14×10^5	2.36×10^5	2.54×10^5	2.69×10^5

3.4 Sensory Properties

In terms of taste, the product falls into like category (6.53) with a range of 5.13–7.92, which indicates a neutral to like very much. On average, the panelists thought that the taste tended to be too sweet, with a slight salty and sour taste. The product color received a good response (6.38) with a range of 5.16 – 7.61 which indicates a neutral to like moderate. Panelists still prefer black dodol, as an effect of the Maillard reaction between reducing sugars, amino acids, and the heating process. The texture score is still in the neutral classification of 5.58 with a range of 3.99–7.16, the somewhat dislike – moderate like category.

Table 6. Organoleptics scores of *Arenga pinnata* fruit dodol

No	Parameteres	Average scores	Range scores
1	Color	6.38 ± 1.23	5.14 – 7.61
2	Aroma	7.05 ± 0.99	7.05 – 8.04
3	Taste	6.53 ± 1.40	5.13 – 7.92
4	Texture	5.58 ± 1.58	3.99 – 7.16
5	Overall	6.50 ± 1.06	5.44 – 7.56

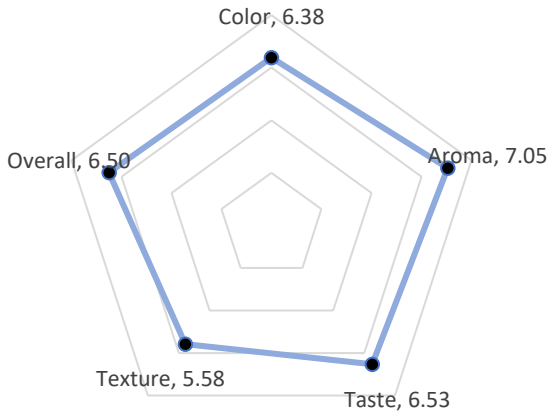

Figure 4. stated the results of the panelist preference test

Based on the Figure 4, the taste and color are the main parameters of consumer attention. The taste and aroma of the product are influenced by the raw materials, formulation, and heating process applied. Sugar palm fruit tends not to have a distinctive aroma (neutral), so it does not affect the aroma of the product. However, prolonged heating at elevated temperatures generates aromatic compounds, contributing to a distinctive aroma. Drying proceses, widely utilized in the food industry to prevent biological degradation, are known to affect flavor retention (Kim *et al.*, 2020). The character of dodol is usually dark brown in color, with a sweet taste and sticky texture.

Table 6 stated the results of the panelist preference test. In terms of taste, the product falls into like category (6.53) with a range of 5.13–7.92, which indicates a neutral to like very much. On average, the panelists thought that the taste tended to be too sweet, with a slight salty and sour taste. The product color received a good response (6.38) with a range of 5.16 – 7.61 which indicates a neutral to like moderate. Panelists still prefer black dodol, as an effect of the Maillard reaction between reducing sugars, amino acids, and the heating process. Both the maillard reaction and sugar caramelization contribute to the browning of foods (Seow *et al.*, 2021). There are three types of browning in food production: Mailard reaction, which involves amino acids/protein-reducing sugars; caramelization, which occurs with carbohydrates: and enzymatic oxidation of polyphenols by polyphenol oxidase (Han *et al.*, 2022).

The texture score is still in the neutral classification of 5.58 with a range of 3.99–7.16, the somewhat dislike – moderate like category. On average, the panellists gave a neutral score for texture because the product's texture is not uniform. On the other hand, the aroma was well received with a score of 7.05 with a range of 6.06 – 8.04, somewhat – very like category. In terms of overall parameters, the panellists gave an average score of 6.50 which shows their liking for the product being tested, with a range of 5.44 – 7.56, neutral–like category. Based on figure 1, panellist gave higher scores for aroma and texture of product, 7.05 and 6.53 point, respectively, while the texture parameter has the smallest score (5.58) was caused an uniform texture. The texture prameters influencing panelist acceptance are the correlation between firmness, springiness, and adhesiveness. These parameters are formed due to the heating process during dodol production, which results in gelatinization and retrogadation when the product cools (Kusumawati and Basmal, 2015). According to opinion Seow *et al.* (2021), dodol is appreciated by consumers for its enjoyable chewiness, and it is suggested that panelists believe it should maintain a certain firmness to enchance the chewing experience.

Based on the panelists' responses, there are several improvements in the sugar palm fruit dodol making process to increase product acceptance, including washing the palm fruit thoroughly to remove adhering salt, using a chopper to pound the palm fruit for a more uniform texture, first cooking the palm fruit dregs to reduce the water content. and eliminating microbial contaminants, reducing the amount of sugar added in the formulation to reduce the sweet taste, using low to medium heat during cooking to prevent excessive burning and darkening of color, and ensuring thorough cooking until the mixture reaches a solid consistency.

Conclusion

Based on the findings, *Arenga pinnata* fruit dodol can be stored for up to 30 days at room temperature while maintaining microbial safety according to Indonesian regulations. The addition of sorbate as a non-coating treatment (SNC) resulted in the most favorable characteristics in terms of texture profile and microbial growth. The microstructure analysis confirmed the uneven texture observed by the sensory panel. Overall, this study demonstrates the potential of *Arenga pinnata* fruit dodol as a local delicacy with an extended shelf life.

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Author contributions

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Availability of data and materials

All data and materials are presented in the manuscript.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors approved the manuscript and this submission for publication in Food Biophysics.

Competing interests

All authors declared that they have no competing interest.

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