

# Analyzing Moisture Content and Water Activity of Freeze-Dried Beef Rendang Across Different Coconut Milk Percentages

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## Abstract

Beef rendang, a traditional prolonged cooking dish from Malaysia and Indonesia, reflects the Quranic principles of preservation and nourishment, emphasizing the consumption of pure, lawful, and wholesome food (Surah Al-Baqarah 2:172). Its preparation, combining meat protein, coconut milk, and spices, symbolizes the bounty and sustenance provided by Allah. While the dish is known for its rich flavors and extended shelf life, prolonged cooking can lead to moisture loss and alterations in water activity (aw), both crucial for maintaining food safety and quality. This study examines the impact of varying coconut milk concentrations on the moisture content and water activity of freeze-dried beef rendang. Samples were prepared with coconut milk concentrations of 0%, 25%, 50%, 75%, 100%, and 125%, cooked for durations ranging from 0 to 4 hours at 120°C, and subjected to freeze-drying. Moisture content analysis revealed reductions ranging from 2% to 10%, demonstrating effective moisture removal across samples. However, water activity analysis indicated significant differences in the availability of free water, likely influenced by coconut milk's fat and water-binding properties. These findings highlight how coconut milk affects initial moisture levels, while freeze-drying stabilizes the final moisture content. The nuanced understanding of water activity reflects the balance in preservation processes, resonating with the Quranic call for equilibrium and purity in food preparation (Surah Al-Baqarah 2:168). This study emphasizes optimizing cooking methods to preserve the quality and safety of beef rendang while aligning with Islamic values of sustainability and stewardship.

## 1. Introduction

Food preservation has been an essential human endeavor throughout history, aimed at ensuring the availability of sustenance while maintaining safety, quality, and nutritional value. In Islamic teachings, the Quran emphasizes the importance of consuming lawful (halal) and wholesome (tayyib) food, as reflected in Surah Al-Baqarah (2:172): "O you who have believed, eat from the good things which We have provided for you and be grateful to

Allah if it is [indeed] Him that you worship." Furthermore, the Quran encourages moderation and discourages wastefulness, as stated in Surah Al-Isra (17:27): "Indeed, the wasteful are brothers of the devils." Beef rendang is a traditional Malaysian and Indonesian dish that has gained international acclaim for its rich flavor and complex cooking process. Originating from the Minangkabau ethnic group in West Sumatra, rendang is typically made by slow-cooking beef in a mixture of coconut milk, spices, and other aromatics until the liquid evaporates and the meat becomes tender, flavorful, and coated in a thick, aromatic paste [1]. This dish exemplifies the harmonious utilization of Allah's provisions, combining sustenance and preservation. However, the prolonged cooking process involved in preparing beef rendang often leads to significant moisture loss, influencing its texture, water activity ( $a_w$ ), and overall quality.

Rendang can be made by variety of meat protein including beef, chicken, and shellfish such as cockles and oysters. Cooking time for beef rendang is longer than for chicken rendang. Malaysian rendang is often cooked at temperatures between 90°C and 120°C for as long as five hours [2]. The prolonged cooking time is crucial for developing the dish's characteristic taste and texture, as well as for its preservation qualities. Rendang's unique preparation method, which involves reducing moisture content through extended cooking, contributes to its long shelf life, even in tropical climates where spoilage is a significant concern. This attribute has made rendang not only a culinary symbol of traditional cuisine but also a subject of scientific interest, particularly in studies focusing on food preservation and safety [3]. The reduction in moisture content and water activity ( $a_w$ ) during the cooking process is critical, as these factors play a significant role in inhibiting microbial growth, thus enhancing the dish's safety and storage potential [4].

Recent research has emphasized the importance of understanding the relationship between moisture content, water activity, and the quality of traditional foods like rendang. Studies have shown that while low water activity is beneficial for extending shelf life, it may also affect the sensory properties of the food, such as texture and flavor [5]. Furthermore, the increasing interest in the commercialization of traditional dishes has led to a growing body of research on optimizing cooking methods to maintain both quality and safety [6].

In recent years, there has been a growing interest in the freeze-drying of traditional foods like rendang to extend their shelf life while maintaining their sensory attributes. Freeze-drying, or lyophilization, is a dehydration process typically used to preserve perishable materials, where water is removed by sublimation under low pressure and temperature conditions [7]. This method is particularly suitable for rendang, which, after its prolonged cooking, already has a relatively low moisture content, making it an excellent candidate for freeze-drying. The final product is lightweight, easy to transport, and has a significantly extended shelf life, making it attractive for both domestic and international markets.

In light of Quranic principles of balance, purity, and sustainability, this study investigates the effects of varying coconut milk concentrations on the moisture content and water activity of freeze-dried beef rendang. By understanding these factors, the research seeks to provide insights into optimizing the cooking process to balance quality, shelf life, and safety, which is crucial for both domestic cooking and commercial production [8], aligning modern food science with Islamic values.

## 2. Methodology

### 2.1 Sample Preparation

All ingredients were purchased at Malaysia's flea market, Seri Kembangan Selangor. A 12-kilogram lean beef shank portion was sliced into 3x5x5 cm pieces, cooked for two hours on a gas stove, and then allowed to cool for one hour at room temperature. After being manually shredded, the boiled flesh was kept in a cooler (6–8 °C) for the entire night. In an automatic braising pan (Salsamat, Nilma, Parma, Italy), coconut milk (10 kg), kerisik (400 g), blended dried chilli (1 kg), blended red onion (3 kg), blended garlic (1 kg), blended galangal (120 g), blended lemongrass (1.5 kg), tamarind slice (100 g), blended ginger (120 g), coriander seed powder (100 g), fennel powder (50 g), cumin powder (50 g), sugar (200 g), and salt (100 g). All the rendang ingredients were cooked in different percentages of coconut milk (0%, 25%, 50%, 75%, 100% and 125%), followed by cooking in tandem with the shredded beef for 1 to 4 hours, with one hour intervals that corresponded to T1 (0 hour), T2 (1 hour), T3 (2 hour), T4 (3 hour), and T5 (4 hour), respectively. All the samples were freeze-dried before subjected to further analysis.

### 2.2 Moisture Content Analysis

The moisture analyser (MX-50) method was used to determine the beef rendang's moisture content [9].

### 2.3 Water Activity

The water activity of the beef rendang samples were analyzed using Aqualab water activity meter (Model series 4TE, Decagon Device Inc., USA).

## 2.4 Statistical Analysis

To find the significant difference between means of different coconut milk percentages in freeze dried rendang at the 5% level, all data were examined using the Minitab software for one-way ANOVA, followed by Tukey's test. A statistically significant p-value was defined as less than 0.05.

## 3. Results and Discussions

### 3.1 Moisture Content

Moisture content is a critical parameter in the preparation of beef rendang, influencing both the quality and shelf life of the dish. During the slow-cooking process, the moisture content of the beef is gradually reduced as the meat is simmered in coconut milk and a blend of spices. This reduction in moisture is essential not only for achieving the desired texture and flavor but also for enhancing the dish's preservation qualities. In traditional food preservation, lower moisture content is associated with a reduction in water activity (aw), which directly impacts the growth of microorganisms. A lower moisture content results in a firmer texture and contributes to the deep, rich flavor profile characteristic of rendang [4]. The extended cooking process, which often lasts several hours, helps to break down the collagen in the beef, making it tender while simultaneously evaporating the water, thus concentrating the flavors and reducing the overall moisture content. The significance of moisture content in rendang extends beyond taste and texture; it also plays a crucial role in the dish's long shelf life. Due to its low moisture content, beef rendang can be stored at room temperature for extended periods without significant risk of spoilage, which is particularly advantageous in regions with limited refrigeration facilities. This makes rendang not only a beloved cultural dish but also a practical food for long-term storage and transport [5]. However, it's important to balance moisture reduction with maintaining the quality of the dish. Excessive loss of moisture can lead to an overly dry and tough product, which may detract from the desired sensory characteristics. Therefore, optimizing the cooking duration and temperature is key to ensuring that the moisture content is sufficiently reduced to extend shelf life while preserving the texture and flavor that make rendang so distinctive [3].

In this study, the results of moisture content in freeze-dries rendang with different percentages of coconut milk ranging between 2% to 10% (Table 1). Freeze-drying is known for its efficiency in removing moisture from food products. The range of 2% to 10% moisture content indicates that the freeze-drying process effectively reduced the moisture content of the beef rendang to a level typical for shelf-stable, dried products. Furthermore, values within this range are low enough to minimize the risk of microbial growth, which is crucial for extending the shelf life of the product. Foods with moisture content below 10% are generally considered dry enough to prevent the growth of most bacteria, yeasts, and molds [10]. Other than that, the variation in moisture content could be attributed to differences in the initial composition of the rendang, particularly the varying amounts of coconut milk. While freeze-drying aims to remove moisture uniformly, the initial water content and fat composition, influenced by coconut milk levels, could lead to slight differences in the final moisture content. The food matrix, including the interaction between proteins, fats, and water, could also play a role in the retention of moisture. For example, the fats from coconut milk might encapsulate some moisture, making it slightly more resistant to removal during freeze-drying, which could explain why some samples show higher moisture content closer to 10%. In summary, freeze-drying affects the moisture content in beef rendang, which is a pivotal factor that affects the dish's quality, safety, and longevity.

**Table 1** Moisture content of prolonged cooking beef rendang with different percentages of coconut milk

Heating time (hr)	Moisture contents					
	0%	25%	50%	75%	100%	125%
0 hr	8.32±0.652 <sup>B</sup>	7.93±0.819 <sup>B</sup>	10.66±0.069 <sup>A</sup>	2.03±0.087 <sup>C</sup>	3.70±0.799 <sup>C</sup>	9.38±0.619 <sup>AB</sup>
1 hr	8.54±0.108 <sup>A</sup>	1.39±0.150 <sup>C</sup>	7.56±0.513 <sup>A</sup>	7.65±0.948 <sup>A</sup>	6.11±0.085 <sup>B</sup>	8.35±0.621 <sup>A</sup>
2 hr	7.31±0.146 <sup>AB</sup>	4.40±0.068 <sup>C</sup>	8.23±0.413 <sup>A</sup>	7.61±0.601 <sup>AB</sup>	5.02±0.905 <sup>C</sup>	6.63±0.300 <sup>B</sup>
3 hr	8.93±0.815 <sup>AB</sup>	10.47±1.165 <sup>A</sup>	7.42±0.628 <sup>BC</sup>	7.46±0.484 <sup>BC</sup>	5.24±0.060 <sup>D</sup>	5.62±0.829 <sup>CD</sup>
4 hr	7.14±0.098 <sup>B</sup>	9.78±0.376 <sup>A</sup>	4.94±1.508 <sup>CD</sup>	6.58±0.420 <sup>BC</sup>	4.21±0.346 <sup>D</sup>	5.68±0.214 <sup>BCD</sup>

Different alphabetical letters within rows indicate significant different ( $P < 0.05$ ) among rendang samples. All data were calculated in replicate analysis with the value of mean  $\pm$  SD. The uppercase letter denotes the significant difference between different coconut milk percentages.

### 3.2 Water Activity (Aw)

Water activity (Aw) is a measure of the availability of water for microbial growth and chemical reactions in food [11]. Unlike total moisture content, which indicates the amount of water present, water activity measures the "free" or unbound water that microorganisms can use for growth. Water activity values range from 0 (completely dry) to 1.0 (pure water). The closer the value is to 1.0, the more available water there is for microbial activity.

In this study, the water activity of freeze-dried beef rendang with different percentages of coconut milk varied ranging between 0.39 to 0.79, where the lowest water activity is shown at the 4-hour cooking time of beef rendang (Table 2). The varying percentages of coconut milk in the rendang could be a significant factor influencing the range of water activity observed. Coconut milk, which contains both water and fat, can affect how water is distributed and bound within the food matrix [12]. The interaction between the fats in coconut milk and the other ingredients in rendang could result in different levels of free water, thereby impacting water activity [13]. For instance, fats may encapsulate some moisture, making it less available for microbial activity, thus lowering the water activity despite the overall moisture content. During prolonged cooking, the water in the coconut milk and other ingredients evaporates, which concentrates the solids (fats, proteins, and carbohydrates) in the dish [14]. The long cooking process enhances the binding of water to other components in the rendang, such as proteins and starches, making the remaining water less available for microbial growth and chemical reactions. This bound water contributes to a lower water activity after freeze-drying. Other than that, prolonged cooking promotes Maillard browning and caramelization, which not only develop complex flavors but also reduce the water activity by further concentrating the food matrix. These reactions can create additional water-binding sites, thereby reducing the amount of free water available and subsequently lowering the water activity after freeze-drying [15]. The slow cooking process also breaks down connective tissues in the beef, resulting in a more tender texture. This breakdown and the integration of fats from the coconut milk into the meat matrix can lead to a more uniform distribution of water, potentially lowering water activity by minimizing pockets of free water.

Foods with water activity below 0.50 are generally very stable and resistant to microbial growth, including bacteria, yeasts, and molds [16]. This is because most spoilage microorganisms require a water activity of at least 0.60 to grow. Therefore, rendang samples in this lower range of water activity are likely to have a significantly extended shelf life and are considered microbiologically safe. As the water activity increases above 0.50, the risk of microbial growth begins to rise [17]. While most pathogenic bacteria cannot grow below a water activity of 0.85, some xerophilic molds and osmotolerant yeasts can grow at lower water activities, particularly in the range of 0.60 to 0.70 [17]. Therefore, rendang samples with water activity (Aw) closer to 0.79 may be more susceptible to spoilage if not stored properly. Higher water activity also promotes certain chemical reactions, such as the Maillard reaction and lipid oxidation, which can affect the flavor, color, and nutritional quality of the food over time [18]. For example, Maillard browning, which occurs between amino acids and reducing sugars, is more likely to occur in foods with a water activity between 0.60 and 0.70 [19], potentially impacting the sensory properties of the rendang. The water activity range of 0.39 to 0.79 in freeze-dried beef rendang reflects the complex interactions between its ingredients, particularly the coconut milk, and the effectiveness of the freeze-drying process. Lower water activity values indicate a highly stable product with minimal microbial risk, while higher values suggest a need for careful storage and monitoring to maintain quality and safety over time.

**Table 2** Water activity (aw) of prolonged cooking beef rendang with different percentages of coconut milk

Heating time (hr)	Water activity (Aw)					
	0%	25%	50%	75%	100%	125%
0 hr	0.540±0.001 <sup>C</sup>	0.492±0.001 <sup>F</sup>	0.796±0.006 <sup>A</sup>	0.531±0.001 <sup>D</sup>	0.686±0.003 <sup>B</sup>	0.522±0.001 <sup>E</sup>
1 hr	0.491±0.001 <sup>B</sup>	0.727±0.002 <sup>A</sup>	0.443±0.001 <sup>C</sup>	0.421±0.001 <sup>E</sup>	0.391±0.004 <sup>F</sup>	0.433±0.001 <sup>D</sup>
2 hr	0.630±0.002 <sup>A</sup>	0.485±0.001 <sup>B</sup>	0.403±0.003 <sup>D</sup>	0.400±0.001 <sup>D</sup>	0.408±0.002 <sup>C</sup>	0.402±0.001 <sup>D</sup>
3 hr	0.656±0.002 <sup>B</sup>	0.756±0.002 <sup>A</sup>	0.412±0.003 <sup>E</sup>	0.405±0.001 <sup>F</sup>	0.431±0.001 <sup>D</sup>	0.508±0.003 <sup>C</sup>
4 hr	0.401±0.001 <sup>C</sup>	0.575±0.001 <sup>A</sup>	0.399±0.001 <sup>C</sup>	0.389±0.003 <sup>D</sup>	0.443±0.003 <sup>B</sup>	0.396±0.001 <sup>C</sup>

Different alphabetical letters within rows indicate significant different (P<0.05) among rendang samples. All data were calculated in replicate analysis with the value of mean ± SD. The uppercase letter denotes the significant difference between different coconut milk percentages.

#### 4. Conclusion

The freeze-drying process successfully reduced the moisture content of the beef rendang to a range of 2% to 10%, indicating that the process is effective in creating a low-moisture product that is suitable for long-term storage. This low moisture content is essential for extending the shelf life of the product and ensuring its safety. Despite the consistent reduction in moisture content, the water activity of the samples varied significantly, ranging from 0.39 to 0.79. This variation indicates that the coconut milk concentration influences the distribution and availability of water within the rendang, even after freeze-drying. Samples with lower water activity (around 0.39) are more stable and less prone to microbial growth and spoilage, while those with higher water activity (closer to 0.79) may require more careful storage conditions to maintain their safety and quality. Following that, the varying coconut milk percentages appear to play a role in determining the water activity of the freeze-dried rendang. Coconut milk, which contains both fat and water, likely affects how water is retained or released during freeze-drying, leading to differences in water activity. This finding suggests that optimizing the coconut milk content in rendang recipes could be important for achieving desired levels of water activity, depending on the intended shelf life and storage conditions. The study highlights the role of coconut milk concentration in influencing the moisture content and water activity (aw) of freeze-dried beef rendang, demonstrating how ingredient proportions can impact food preservation. The freeze-drying process effectively stabilizes moisture levels, but variations in water activity suggest the presence of intricate interactions between ingredients and their binding properties. These findings emphasize the importance of understanding and optimizing preservation methods to maintain food safety, quality, and shelf life. Aligning these conclusions with Quranic sciences and Hadith reveals deeper insights into the spiritual and ethical dimensions of food preservation. The Quran repeatedly emphasizes the consumption of pure, wholesome, and lawful sustenance, as mentioned in Surah Al-Baqarah (2:168): "O mankind, eat from whatever is on earth [that is] lawful and good and do not follow the footsteps of Satan. Indeed, he is to you a clear enemy." Ensuring that preserved food retains its quality and safety aligns with this directive, as it protects the purity of what is consumed. Moreover, the study's focus on reducing waste and improving sustainability resonates with the Hadith of the Prophet Muhammad (peace be upon him): "The son of Adam does not fill a vessel worse than his stomach. It is sufficient for the son of Adam to eat a few mouthfuls to keep him going. If he must, then a third is for his food, a third for his drink, and a third for his breath" (Sunan Ibn Majah, 3349). This Hadith advocates moderation, balance, and mindful consumption, principles that are inherently supported by effective food preservation techniques. In conclusion, the research not only advances food science but also aligns with the Quranic and prophetic emphasis on sustainability, purity, and gratitude for Allah's blessings.

Further research should explore the precise impact of different coconut milk concentrations on the final product's water activity. Experimenting with a broader range of coconut milk percentages could help identify the optimal concentration that balances flavor, texture, and water activity, ensuring both high product quality and safety. Also, future studies should explore the long-term stability of freeze-dried rendang with varying water activity levels, focusing on sensory attributes, nutritional content, and potential spoilage over extended storage periods.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

#### Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Siti Nabilah Karim, Rashidah Sukor, Nuzul Noorahya Janbari, Maimunah Sanny, Alfi Khatib; **data collection:** Siti Nabilah Karim; **analysis and interpretation of results:** Siti Nabilah Karim, Rashidah Sukor; **draft manuscript preparation:** Siti Nabilah Karim, Rashidah Sukor. All authors reviewed the results and approved the final version of the manuscript.*

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