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Effect of size, pre-treatment and freeze-drying duration on the quality characteristics of freeze-dried chicken meat: A pilot study for development of a freeze-dried ready-to-cook Chettinad chicken meat product

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Abstract

A preliminary pilot study was conducted to standardize the meat size, pre-treatment method and freeze-drying duration for the production of freeze-dried, ready-to-cook Chettinad chicken meat product. Boneless chicken breast meat was cut into two sizes (2.0 and 1.5 cm) and subjected to four pre-treatments (fresh, treated with 0.25% turmeric powder, blanched and cooked), followed by freeze-drying for three durations (8, 9 and 10 h). As the primary objective of the experiment was process optimization, each treatment was evaluated using a single observation. Therefore, the results were interpreted descriptively. Freeze-dried meat yield, water activity and rehydration ratio ranged from 21.20-24.40, 0.16-0.39, and 10.1-18.5, respectively, among the treatments. Pre-treatment exerted a greater influence on all three quality attributes than meat size or drying duration and extending freeze-drying beyond 8-9 h produced only marginal improvements. The three drying durations were included as a confirmatory step, to verify that the yield, water activity and rehydration ratio obtained were consistent and to identify the shortest cycle compatible with acceptable quality, so that the product could be developed economically. Based on the combined evaluation of yield, water activity and rehydration characteristics, 2 cm cooked chicken meat chunks were selected as the optimum treatment for developing the freeze-dried ready-to-cook Chettinad chicken product.

Keywords: Freeze-drying (lyophilization), chicken meat, pre-treatment, rehydration ratio, water activity

1. Introduction

Poultry meat, especially chicken, has emerged as the most widely produced and consumed source of animal protein worldwide, owing to its comparatively low cost, favourable protein-to-fat ratio and broad acceptability across cultures and religions ^[1]. Changing lifestyles, increasing workforce participation and a growing preference for convenience have driven strong consumer demand for ready-to-eat and ready-to-cook meat products that combine nutritional quality with ease of preparation and extended shelf life ^[2]. Dried meat products in particular have become popular in the modern market because of their long shelf life, distinctive taste and perceived health benefits, and the type of meat, added ingredients and drying technology employed are all recognized as major determinants of the physicochemical, microbial and sensory quality of the final product ^[3]. Chettinad chicken, a spicy and aromatic preparation originating from the Chettinad region of Tamil Nadu, India, is one such traditional recipe that enjoys wide popularity but is conventionally prepared only from fresh chicken shortly before consumption, limiting its availability as a shelf-stable convenience product.

Freeze-drying, or lyophilization, is regarded as one of the gentlest methods of food dehydration. Water is first frozen and then removed by sublimation under vacuum, which minimizes the thermal degradation, shrinkage and structural collapse commonly associated with conventional hot-air drying, thereby yielding a product with a highly porous structure,

near-instantaneous rehydration, retained nutritional value and extended storage stability at ambient temperature [4, 5]. Early work on freeze-dried poultry established that rehydrated, freeze-dried chicken meat can closely approach the tenderness, juiciness and flavour of the fresh cooked product when raw-material and processing variables are properly controlled [6]. Despite these advantages, the physicochemical and rehydration characteristics of freeze-dried meat are strongly influenced by processing variables such as the size of the meat pieces, the pre-treatment applied before drying and the duration of the freeze-drying cycle, all of which affect moisture removal, porosity and the ability of the dried product to reconstitute to a texture resembling the fresh cooked product [5, 7]. Sample thickness and piece size, in particular, govern the resistance to heat and mass transfer during sublimation and are therefore critical in determining the freeze-drying conditions needed to obtain a product close in quality to the fresh meat [8].

Therefore, standardization of these process variables is a prerequisite for the successful development of a freeze-dried, ready-to-cook traditional Chettinad chicken product with desirable quality attributes. Accordingly, the present pilot study was undertaken to evaluate the combined effect of cube size (2.0 and 1.5 cm), four pre-treatments (fresh, turmeric-treated, blanched and cooked) and three freeze-drying durations (8, 9 and 10 h) on the freeze-dried yield, water activity and rehydration ratio of chicken meat cubes, with the objective of identifying the optimum processing conditions for subsequent development of a freeze-dried, ready-to-cook Chettinad chicken product.

Three freeze-drying durations were deliberately included rather than a single fixed cycle, so that the yield, water activity and rehydration ratio recorded at 8 h could be confirmed against those obtained at 9 and 10 h. Establishing the point beyond which these attributes cease to improve appreciably identifies the shortest cycle capable of delivering an acceptable product, and thereby allows the ready-to-cook Chettinad chicken to be developed economically, since freeze-drying is among the most costly and energy-intensive dehydration operations and its running cost scales directly with the length of the drying cycle [4].

2. Materials and Methods

2.1 Source of meat

Hygienically slaughtered fresh boneless broiler chicken breast meat was procured from a commercial poultry processing plant near Udumalpet, Tamil Nadu, India. The meat was transported to the laboratory in a clean, expanded polystyrene (thermocool) container under chilled hygienic conditions to preserve its quality and freshness. Upon arrival, the meat was stored at 4 ± 1 °C until it attained the desired core temperature, after which it was subjected to the respective pre-treatment procedures.

2.2 Standardization of lyophilized chicken meat cubes for the preparation of Chettinad chicken

The lyophilization process for chicken breast meat cubes was standardized to develop a high-quality freeze-dried product suitable for the preparation of a ready-to-cook Chettinad chicken. For this purpose, boneless chicken breast meat was cut into two cube sizes (1.5 cm $\times$ 1.5 cm $\times$ 1.5 cm and 2.0 cm $\times$ 2.0 cm $\times$ 2.0 cm), and each size was subjected to four different pre-treatment methods prior to freeze-

drying. Treatments T₁-T₄ denote the 2.0 cm cubes and T₅-T₈ the 1.5 cm cubes, and were as follows:

T₁ and T₅: Untreated chicken meat cubes (control), subjected directly to lyophilization.

T₂ and T₆: Chicken meat cubes treated with 0.25% turmeric powder and subsequently lyophilized.

T₃ and T₇: Chicken meat cubes blanched before lyophilization.

T₄ and T₈: Chicken meat cubes cooked until the internal temperature reached 75 °C and then subjected to lyophilization.

All samples were freeze-dried under identical operating conditions to ensure uniform processing. This enabled a systematic evaluation of the influence of meat cube size and pre-treatment on the physicochemical properties and rehydration characteristics of the lyophilized chicken meat cubes, thereby facilitating selection of the most suitable treatment for further product development.

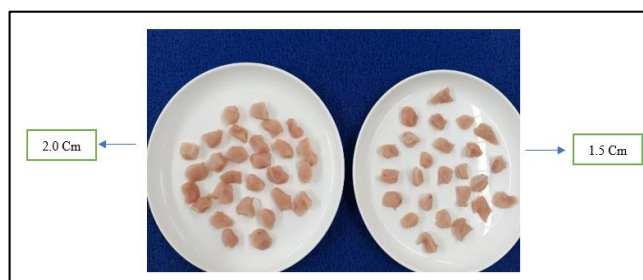


Fig 1: Chicken breast meat chunks prepared for freeze-drying

2.3 Pre-treatment procedures for chicken meat

Conditioned, chilled boneless chicken breast meat was used for the study. The meat was manually cut into the two cube sizes described above and each size was subjected to the four pre-treatment methods below prior to freeze-drying.

2.3.1 Fresh meat (T₁ and T₅)

Fresh boneless broiler chicken breast meat cubes of both predetermined sizes (1.5 cm and 2.0 cm) were used as the control without any pre-treatment. The samples were directly frozen and subsequently subjected to freeze-drying (lyophilization).

2.3.2 Turmeric treatment (T₂ and T₆)

Fresh boneless broiler chicken breast meat chunks were treated with 0.25% turmeric powder (w/w) for a standardized holding period of [insert duration] at 4 ± 1 °C. Turmeric is widely used as a natural additive in meat products for its antioxidant properties and its influence on colour and cooking loss [2]. Curcumin, the principal bioactive polyphenol of turmeric, has been shown to slow oxidative changes and improve colour stability when incorporated into meat products such as vacuum-packed meatloaf [9]. After the turmeric treatment, the samples were spread uniformly on freezing trays and frozen prior to lyophilization.



Fig 2: Turmeric-treated chicken meat prior to freezing

2.3.3 Blanching (T_3 and T_7)

Fresh boneless broiler chicken breast meat cubes were blanched by immersion in hot water maintained at 90 °C for 2 minutes, a treatment commonly used to inactivate enzymes and stabilize colour and texture prior to further processing^[10]. Blanching at comparable time-temperature combinations has been shown to substantially reduce oxidative enzyme activity and to accelerate subsequent drying in other food matrices^[11], and a short thermal pre-treatment step of this kind is similarly recognized to reduce microbial load and stabilize quality in meat intended for ready-to-eat or home-meal-replacement products^[12]. Immediately after blanching, the cubes were transferred to chilled water (4±1 °C) to arrest further heat treatment. The samples were then drained to remove excess surface moisture and subsequently frozen prior to lyophilization.

2.3.4 Cooking (T_4 and T_8)

Fresh boneless broiler chicken breast meat cubes were cooked in hot water to reach an internal core temperature of 75 °C, as measured using a calibrated digital probe thermometer. After cooking, the cubes were drained and allowed to cool to room temperature before being transferred to freezing trays and frozen prior to lyophilization.

2.4 Freezing of fresh and pre-treated boneless chicken breast meat

Fresh and pre-treated boneless chicken breast meat samples (T_1 - T_8) were arranged in a single layer on stainless steel trays lined with butter paper to prevent the samples from adhering to the tray surface. The trays were placed in a blast freezer and frozen at -40 °C for 12 hours to ensure complete freezing before lyophilization.

2.5 Freeze-drying (lyophilization) of fresh and pre-treated boneless chicken breast meat

The freeze-drying process for fresh and pre-treated boneless chicken breast meat was standardized based on the principles described by Ratti^[4] and Fellows^[10], with suitable modifications.

After freezing, the chicken meat cubes were uniformly arranged in a single layer on the trays of a freeze dryer (Model: FD50, ANM Industries, Mumbai, India) and immediately transferred into the drying chamber to

minimize thawing. During freeze-drying, the condenser temperature was maintained between -70 and -80 °C, and the chamber pressure at below 10 Pa, values consistent with condenser and chamber-pressure ranges recommended for food-grade freeze-drying^[5]. Layer thickness and piece size were kept uniform across replicates, since sample thickness has been shown to be a critical determinant of the process conditions required to obtain freeze-dried poultry meat of quality comparable to the fresh product [8]. Samples were lyophilized for three different durations (8, 9 and 10 h) under these standardized operating conditions.

The three durations were adopted as a confirmatory measure rather than as an end in themselves. Comparing the freeze-drying yield, water activity and rehydration ratio across 8, 9 and 10 h was intended both to verify the consistency of these attributes and to establish the minimum drying time compatible with acceptable product quality, so that the ready-to-cook Chettinad chicken product could subsequently be manufactured on an economical basis.

At the end of each drying cycle, the freeze-dried chicken meat cubes were removed from the freeze dryer and immediately evaluated for freeze-drying yield, water activity and rehydration ratio to determine the combination of cube size, pre-treatment and drying duration best suited for subsequent packaging, storage and quality evaluation. Water activity was assessed because, next to temperature, it is one of the most important parameters governing the chemical, microbial and physical stability of processed foods during storage^[13].

2.6 Analytical methods

2.6.1 Freeze-drying yield

The freeze-drying yield was determined gravimetrically. Samples were weighed immediately before freezing and again immediately after removal from the freeze dryer using an electronic balance. Yield was calculated as:

Freeze-drying yield (%) = (weight of freeze-dried sample/weight of sample before freeze-drying) × 100

2.6.2 Water activity

The water activity of the freeze-dried cubes was measured at 25 °C using a calibrated water activity meter (Aqua Lab water activity meter, Decagon Devices Inc., Washington, USA; accuracy±0.02 a_w). Samples were ground to a uniform particle size and placed in the sample cup, and readings were recorded once the instrument indicated equilibrium.

2.6.3 Rehydration ratio

The rehydration characteristics of the lyophilized meat and non-meat ingredients were determined by adopting the method described by Da-Wen Sun^[14] with slight modifications. Five grams of each lyophilized sample were immersed in 100 ml of boiling water and allowed to rehydrate for 20 minutes. After rehydration, the samples were drained on a stainless-steel sieve for 3 minutes to remove excess surface water. The rehydrated samples were immediately weighed using a digital analytical balance. The rehydration ratio was calculated from the weight of the sample before and after rehydration using the following equation:

Rehydration Ratio (RR) = Weight of rehydrated sample (W_2g)/Weight of dried sample (W_1g)

Where,

W_1 = Weight of the lyophilized sample before rehydration (g)

W_2 = Weight of the rehydrated sample (g)

2.7 Statistical treatment

As the objective of this pilot study was process optimization rather than statistical comparison, a single observation was recorded for each of the eight treatment combinations (T_1 - T_8) at each of the three freeze-drying durations (8, 9 and 10 h). The data are therefore presented and interpreted descriptively, without formal statistical analysis.

3. Results

3.1 Yield after freeze-drying

The yield of freeze-dried chicken meat obtained after different pre-treatments and freeze-drying durations is presented in Table 1. The yield ranged from 21.20 to 24.40%, depending on the pre-treatment, cube size and drying duration.

Table 1: Effect of cube size, pre-treatment and freeze-drying duration on the freeze-drying yield (%) of chicken meat*

Treatment	8 h	9 h	10 h
T_1 : 2 cm cube-Fresh	24.40	24.10	23.90
T_2 : 2 cm cube-Turmeric-treated	24.20	24.20	24.10
T_3 : 2 cm cube-Blanched	22.10	22.50	22.60
T_4 : 2 cm cube-Cooked	21.78	21.34	21.25
T_5 : 1.5 cm cube-Fresh	24.10	24.20	24.00
T_6 : 1.5 cm cube-Turmeric-treated	24.00	24.10	24.10
T_7 : 1.5 cm cube-Blanched	22.31	22.31	22.52
T_8 : 1.5 cm cube-Cooked	22.41	21.3	21.20

*The data presented are single observations obtained during a preliminary pilot study conducted for process optimization. The results are therefore presented descriptively, and no statistical analysis was performed.

Among the 2.0 cm cube treatments, fresh (T_1) and turmeric-treated (T_2) samples recorded the highest yields, ranging from 23.90-24.40% and 24.10-24.20%, respectively. Blanched meat (T_3) showed comparatively lower yields (22.10-22.60%), while cooked meat (T_4) exhibited the lowest yield (21.25-21.78%). A similar trend was observed among the 1.5 cm cube treatments, where fresh (T_5) and turmeric-treated (T_6) samples maintained relatively higher yields (24.00-24.20% and 24.00-24.10%, respectively),

whereas blanched (T_7) and cooked (T_8) samples recorded comparatively lower yields, ranging from 21.20 to 22.52%.

3.2 Water activity

The water activity (a_w) of freeze-dried chicken meat ranged from 0.16 to 0.39 (Table 2). Among the 2.0 cm cube treatments, cooked samples (T_4) exhibited the lowest water activity, decreasing from 0.19 at 8 h to 0.17 at 10 h, indicating efficient moisture removal during freeze-drying. Fresh (T_1) and blanched (T_3) samples also showed relatively low water activity values (0.22-0.25), whereas turmeric-treated samples (T_2) retained comparatively higher water activity (0.37-0.39), suggesting greater residual moisture.

Table 2: Effect of cube size, pre-treatment and freeze-drying duration on the water activity of freeze-dried chicken meat*

Treatment	8 h	9 h	10 h
T_1 : 2 cm cube-Fresh	0.25	0.23	0.24
T_2 : 2 cm cube-Turmeric-treated	0.39	0.38	0.37
T_3 : 2 cm cube-Blanched	0.24	0.23	0.22
T_4 : 2 cm cube-Cooked	0.19	0.18	0.17
T_5 : 1.5 cm cube-Fresh	0.24	0.23	0.23
T_6 : 1.5 cm cube-Turmeric-treated	0.26	0.26	0.25
T_7 : 1.5 cm cube-Blanched	0.22	0.21	0.19
T_8 : 1.5 cm cube-Cooked	0.17	0.16	0.16

*The data presented are single observations obtained during a preliminary pilot study conducted for process optimization. The results are therefore presented descriptively, and no statistical analysis was performed.

Similarly, among the 1.5 cm cube treatments, cooked samples (T_8) recorded the lowest water activity (0.17, 0.16 and 0.16 at 8, 9 and 10 h, respectively), followed by blanched samples (T_7). Turmeric-treated samples (T_6) exhibited comparatively higher water activity values (0.25-0.26).

3.3 Rehydration ratio

The rehydration ratio ranged from 10.1 to 18.5 among the different treatments (Table 3). Cooked meat exhibited the highest rehydration ratio in both cube sizes. The 2.0 cm cooked cubes (T_4) showed rehydration ratios of 18.1, 18.3 and 18.5 after 8, 9 and 10 h of freeze-drying, while the 1.5 cm cooked cubes (T_8) recorded values of 18.0, 18.1 and 18.2, respectively.

Table 3: Effect of cube size, pre-treatment and freeze-drying duration on the rehydration ratio (%) of freeze-dried chicken meat*

Treatment	8 h	9 h	10 h
T_1 : 2 cm cube-Fresh	12.30	12.50	12.70
T_2 : 2 cm cube-Turmeric-treated	10.10	10.70	10.90
T_3 : 2 cm cube-Blanched	15.00	15.10	15.30
T_4 : 2 cm cube-Cooked	18.10	18.30	18.50
T_5 : 1.5 cm cube-Fresh	12.20	12.50	12.60
T_6 : 1.5 cm cube-Turmeric-treated	10.50	10.70	10.90
T_7 : 1.5 cm cube-Blanched	15.10	15.20	15.50
T_8 : 1.5 cm cube-Cooked	18.00	18.10	18.20

*The data presented are single observations obtained during a preliminary pilot study conducted for process optimization. The results are therefore presented descriptively, and no statistical analysis was performed.

Blanched samples (T_3 and T_7) demonstrated intermediate rehydration ratios (15.0-15.5%), whereas fresh samples (T_1 and T_5) exhibited values between 12.2 and 12.7%. Turmeric-treated samples (T_2 and T_6) showed the lowest rehydration ratios (10.1-10.9%).

4. Discussion

The freeze-dried yield was primarily influenced by the pre-treatment rather than the freeze-drying duration. Fresh and turmeric-treated samples retained comparatively higher yields because of lower processing losses before freeze-

drying. In contrast, cooked and blanched samples exhibited lower yields, which could be attributed to moisture and soluble-solid losses during thermal processing prior to freeze-drying^[10]; comparable moisture and mass losses during pre-drying thermal treatments have similarly been reported for cooked and blanched meat systems intended for convenience food formats^[12]. The negligible differences in yield between 8, 9 and 10 h indicate that extending the drying duration beyond 8-9 h did not substantially improve product recovery; from the standpoint of processing efficiency and energy conservation, 8-9 h of freeze-drying therefore appeared sufficient to obtain a satisfactory product yield, consistent with the view that freeze-drying costs rise sharply with processing time and should be minimized wherever product quality permits^[4]. Increasing the freeze-drying duration from 8 to 10 h resulted in only minor variations in yield across all treatments, with several treatments showing a slight reduction in yield as drying time increased, although the differences among drying durations were negligible, in line with reports that freeze-dried yield in meat systems is governed more strongly by pre-treatment and raw-material losses than by drying time once the bulk of the ice has sublimated^[15].

The low water activity values (0.16 to 0.39) obtained in the present study indicate effective moisture removal during freeze-drying, which is essential for improving the storage stability of dehydrated meat products. Water activity is one of the primary factors governing microbial growth as well as chemical and physical deterioration in foods and values below 0.60 are generally considered microbiologically stable^[13]. Among the pre-treatments, cooked samples consistently exhibited the lowest water activity (0.16-0.19), suggesting that cooking prior to freeze-drying enhanced moisture removal through protein denaturation and structural modifications that facilitated ice sublimation. Similar findings were reported by Szymańska *et al.*^[16], who observed water activity values below 0.44 for freeze-dried chicken breast meat, demonstrating the effectiveness of freeze-drying in reducing available water. Likewise, Mierzwińska *et al.*^[17] reported water activity values ranging from 0.19 to 0.29 for freeze-dried poultry meat, irrespective of pulsed electric field pre-treatment, indicating that freeze-drying effectively lowered water activity to levels suitable for prolonged storage. The authors further suggested that pre-treatments influencing muscle microstructure affected moisture migration and drying efficiency, which is consistent with the present findings, where cooked and blanched samples exhibited lower water activity than turmeric-treated samples. In contrast, turmeric-treated samples retained comparatively higher water activity (0.25-0.39), possibly due to the presence of dissolved solids and interactions between turmeric constituents and water, which may have hindered moisture diffusion during drying^[2]. Although water activity decreased slightly with increasing freeze-drying duration, the reduction beyond 9 h was minimal, indicating that most removable moisture had already been eliminated during the initial stages of drying. This observation is in agreement with Labuza^[13], who reported that the removal of the remaining bound water proceeds slowly after the bulk of the ice has sublimated, making prolonged drying less effective while increasing processing time and energy consumption. Therefore, a freeze-drying duration of 8-9 h appears sufficient to achieve the desired low water activity and ensure the storage

stability of the developed freeze-dried ready-to-cook chicken product.

The rehydration ratio is an important quality attribute of freeze-dried meat, reflecting the preservation of tissue structure during dehydration and the ability of the product to absorb water during reconstitution. In the present study, the rehydration ratio ranged from 10.10 to 18.50%, with cooked samples consistently exhibiting the highest values irrespective of cube size. The superior rehydration capacity of cooked meat suggests that thermal denaturation of muscle proteins before freeze-drying promoted the formation of a stable, porous microstructure, facilitating rapid water absorption during reconstitution. This finding agrees with Nowak and Jakubczyk^[5], who reported that ice sublimation during freeze-drying creates an interconnected porous matrix that enhances water uptake while minimizing structural collapse. Similarly, Aksoy *et al.*^[15] and Oyinloye and Yoon^[7] observed that freeze-dried meat exhibited higher rehydration capacity than hot-air-or vacuum-dried meat due to better preservation of the cellular structure.

Blanching also improved the rehydration ratio compared with fresh meat, indicating that mild heat treatment enhanced moisture uptake during reconstitution. Comparable findings were reported by Szymańska *et al.*^[16] and Mierzwińska *et al.*^[17], who demonstrated that appropriate pre-treatments preserved the porous microstructure of freeze-dried poultry meat, resulting in superior water absorption characteristics. In contrast, turmeric-treated samples exhibited the lowest rehydration ratios (10.10-10.90%), possibly due to the deposition of dissolved solids and bioactive compounds that restricted moisture migration during drying and reduced pore accessibility during rehydration^[2, 18].

Only a slight increase in the rehydration ratio was observed with increasing freeze-drying duration from 8 to 10 h, with negligible improvement beyond 9 h. This finding is consistent with Ratti^[4], who reported that extending the freeze-drying process beyond the optimum endpoint provides little additional improvement in rehydration while increasing processing time and energy consumption. Overall, the results indicate that pre-treatment exerted a greater influence on the rehydration characteristics of freeze-dried chicken meat than drying duration, with cooking followed by an 8-9 h freeze-drying cycle providing the most desirable rehydration properties for the development of a high-quality ready-to-cook product.

Considered together, the three drying durations served a confirmatory purpose. The close agreement among the 8, 9 and 10 h values for all three attributes, with yield varying by no more than about 1.2 percentage points within any single treatment, water activity by 0.01 to 0.03 and rehydration ratio by 0.2 to 0.8 percentage points, indicates that the quality of the dried cubes was essentially established by the end of the 8 h cycle. Extending the cycle from 8 to 10 h therefore increases freeze-dryer occupancy by a quarter, together with a corresponding rise in condenser and vacuum-pump energy demand, without a commensurate gain in product quality. As the cost of freeze-drying is largely a function of cycle length^[4, 5], restricting the cycle to 8 to 9 h is an important factor in making a freeze-dried ready-to-cook Chettinad chicken commercially realistic, and this economic consideration was therefore weighed alongside the quality data in selecting the final processing conditions.

Taken together, these findings are consistent with the principle that freeze-drying, when properly standardized, preserves the porous, sponge-like matrix created during freezing and sublimation, allowing efficient moisture removal and rapid rehydration compared with conventional hot-air drying^[4, 5, 10]. This general trend is well documented in the wider meat-drying literature: freeze-dried, rehydrated poultry meat has long been shown to attain sensory and physical quality closer to that of the fresh cooked product than meat processed by other drying or storage regimes^[6], and more recent comparative work confirms that appropriately pre-treated and freeze-dried meat outperforms hot-air and vacuum-dried alternatives in porosity, colour retention and rehydration capacity^[3, 8]. The results of this pilot study indicate that pre-treatment, rather than cube size or drying duration, is the dominant factor governing the freeze-drying yield, water activity and rehydration characteristics of chicken meat cubes.

5. Conclusion

The pilot study demonstrated that pre-treatment had a greater influence on the quality characteristics of freeze-dried chicken meat than cube size or freeze-drying duration. Fresh and turmeric-treated samples produced the highest freeze-dried yield, whereas cooked samples exhibited the lowest water activity and the highest rehydration ratio, indicating superior drying efficiency and reconstitution properties. The differences between 8, 9 and 10 h of freeze-drying were relatively small for all quality attributes, suggesting that extending the drying duration beyond 8-9 h offers limited practical advantage while increasing processing time and energy consumption. The optimum processing conditions selected for subsequent experiments were therefore based on the combined evaluation of yield, water activity and rehydration characteristics.

The inclusion of three drying durations thus served to confirm that the yield, water activity and rehydration ratio achieved at 8 h were consistent rather than incidental, and identified 8 to 9 h as the shortest economically defensible cycle for producing the ready-to-cook product on a commercial scale.

Based on the overall evaluation of freeze-drying yield, rehydration characteristics and water activity 2 cm cooked chicken meat cubes were selected for the preparation of the freeze-dried, ready-to-cook Chettinad chicken product. After reconstitution, the 2 cm cooked chicken meat cubes closely resembled the original Chettinad chicken chunks in size and appearance, thereby maintaining the authentic appearance of the traditional product while ensuring desirable quality attributes.

6. Acknowledgements

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7. Conflict of Interest

The authors declare that they have no conflict of interest

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