
Development of a freeze-dried durian sticky rice product with optimized coconut milk content

Ninlanon, W.^{1*}, Puttame, K.¹, Sangsuwan, S.¹, Sawadikarn, J.¹, Ratprakhon, K.¹, Wanich English, U.² and Sumana, B.³

¹Faculty of Agricultural Technology, Rambhai Barni Rajabhat University, Chanthaburi, Thailand;

²Faculty of Science and Technology, Rambhai Barni Rajabhat University, Chanthaburi, Thailand;

³Faculty of Agro-industrial Technology, Rajamangala University of Technology Tawan-ok, Chanthaburi campus, Chanthaburi, Thailand.

Ninlanon, W., Puttame, K., Sangsuwan, S., Sawadikarn, J., Ratprakhon, K., Wanich English, U. and Sumana, B. (2026). Development of a freeze-dried durian sticky rice product with optimized coconut milk content. *International Journal of Agricultural Technology* 22(5):2271-2280.

Abstract Freeze-dried durian sticky rice and the impact of various levels of coconut milk on the quality characteristics were developed. The results were not significantly differed between the treatments concerning color values (L^* 81.68-81.82, a^* 3.66-3.68, and b^* 32.67-33.43; $p>0.05$). The amount of coconut milk increased the water activity and moisture content of the product was found to decrease from 0.48 (1.91%) in 100 ml formula to 0.20 (1.51%) in 200 ml formula. Texture characteristics revealed that the value of hardness decreased significantly from 287.42 N in 100 ml formula to 250.81 N in 200 ml formula ($p\leq 0.05$). The low water activity level of the products was not detected *Escherichia coli* and *Staphylococci aureus* and all the samples were complied with microbiological requirements for dried foods. The results for consumer acceptability showed that a consumer rating of 7.24 on the eating quality of 150 ml coconut milk added formula was obtained to be the acceptance of taste. However, increasing coconut milk was found to cause significant decreasing of moisture, texture characteristics and consumer acceptability of freeze-dried durian sticky rice. At 150 ml level of coconut milk added to formulation can be suggested for best product quality in terms of texture characteristics and consumer acceptability and also can be used in the food industry for an edible shelf-stable product of Thai dessert.

Keywords: Durian sticky rice, Freeze-drying, Coconut milk

Introduction

Durian (*Durio zibethinus* Murr) has known as one of the most favored tropical fruits in Southeast Asia due to the unique taste, smell and creaminess (Brown, 1997). Thailand now is one of the leading exporters in durian products; fresh and processed. The number of durian product consumers increased significantly in recent year which led to more and more varied value-added

* **Corresponding Author:** Waritchon, N.; **Email:** waritchon.n@rbru.ac.th

products created from the durian. The most favorite and traditionally prepared dessert is sticky rice. Sticky rice is prepared by mixing the cooked glutinous rice with coconut milk, sugar, and ripe durian flesh, it is served fresh and favored by consumers in peak season of durian season. However, the typical sticky rice is rarely distributed in general market since it is susceptible to decomposition due to low shelf-life, storage characteristics with high moisture content and coconut milk content that stimulate microbial spoilage and food product instability. The undesirable textural changes like "hardening of sticky rice layer" can negatively affect consumer's acceptance on the product (Sriwattana and Noomhorm, 2013).

Freeze-drying, being a widely adopted technique for heat-sensitive food products in food industry, consists of removing water under vacuum condition at very low temperature, which helped to preserve visual appearance, flavor and structure of the food products effectively than conventional drying techniques (Ratti, 2001). A number of fruit-based food products have already been successfully freeze-dried and evaluated for its extension in shelf life while sustaining product quality without considerable damage to it. These include mango, banana, longan, durian products etc. (Phoungchandang and Woods, 2000; Kerdpi boon *et al.*, 2014). Further, decreasing water activity of freeze-dried food products could improve their microbial stability. Quality of freeze-dried food products is one of the most critical aspects and this greatly depends on the composition of the food product. Presence of fats and moisture especially in the coconut milk may exert some influence over the drying characteristics, structural development and organoleptic properties of the freeze-dried durian sticky rice. It is also established that changing of fat and moisture content affects the structural and mechanical properties of starch-based foods (Waritchon and Kunlaporn, 2022). Even though coconut milk is an essential part of durian sticky rice but its contribution to quality of freeze-dried durian sticky rice was not much investigated. Therefore, the aim was to formulate a freeze-dried durian sticky rice and to find out the effect of various concentrations of coconut milk on physiochemical properties, texture characteristics, microbial profile, acceptability and yield of the product.

Materials and methods

Preparation of freeze-dried durian sticky rice

Raw material glutinous rice (variety name is "Khiow Ngu"). The rice were soaked in the water at 25 °C, with soaking time at least 3 h to fully absorb water, then washed and steamed for 15 min at 100 °C. Rice was already partially cooked, steam partially cooked rice were softly mixed then steamed for another

10 min at 100 °C in order to obtain a smooth starch gelatinization before adding into coconut milk. Ripened 'Monthong' durian fruit at 120 days after blooming was chosen for preparation of the durian pure. The durian fruit pulp was blended for 5 min using a food processor to achieve a homogeneous pure. Durian pure was packed in the Polypropylene (PP) bag and refrigerated at 5 °C before use.

Three level of concentration of coconut milk were prepared (100, 150, 200 ml per 300 g of glutinous rice). Salt and sugar were added to the coconut milk as flavor agents, and it was mixed with warm fresh steamed rice to attain uniformity in the absorption of coconut milk. The coconut sticky rice mixture was rough blended for a homogeneity and equilibrate for 5 h at approximately 25 °C before molds was put in. Durian pure were placed at the bottom, covered with the coconut sticky rice product (Figure 1). The prepare samples were taken and freeze drying; the samples were pre-freezing, then frozen at 45 °C for 2 h for complete freezing, and freeze drying under the condition at 45-68 °C for 18 h, used freeze dryer (model FD-series, Labconco, USA). The freeze-dried durian sticky rice was packed into Aluminium foil zipper bag and store at ambient temperature (25 °C) before analysis.

Product quality evaluation

The quality of freeze-dried durian sticky rice was analyzed in terms of physico-chemical, microbiological and sensory evaluations. Color value of the product (L^* , a^* and b^*) was measured by colorimeter (CR-400, Konica Minolta, Japan) according to the CIE color space. For each sample, color value was analyzed in three times of replicate. Texture of the products was analyzed by Texture analyzer (TA-XT2i, Stable Micro Systems, UK) using hardness for each sample. Moisture content was analyzed by using moisture analyzer (MA35, Sartorius, Germany), while water activity (a_w) was determined by water activity meter (Decagon Devices, USA). Microbiological analysis was performed by enumeration of total aerobic plate count, Coliforms, *Escherichia coli*, *Staphylococcus aureus*, yeast and mold by standard methods according to AOAC (1990). For sensory evaluation, a total of 30 untrained panelists was used to analyze attributes such as appearance, color, flavor, texture and overall acceptability. The products samples were served to the panelist in random order. The panelists were asked to score the samples on a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely). Products quality was accepted when the mean score was between 7 and 8. The yield of the product were presented as percentage (%) based on ratio of weight of freeze-dried product weight on weight of initial raw materials weight before freeze drying.

Experimental design and statistical analysis

All physicochemical analyses were set up according to CRD (Completely Randomized Design). Sensory analyses were designed according to RCBD (Randomized Complete Block Design) by using panelists as block in order to minimize the variations due to the evaluators. All experiments were conducted in triple replication ($n=3$). Data were analyzed using ANOVA (Analysis of variance) with statistical software and means comparison between treatments were assessed by Duncan's New Multiple Range Test (DMRT). Significance was tested with $p \leq 0.05$, in 95% confidence interval.

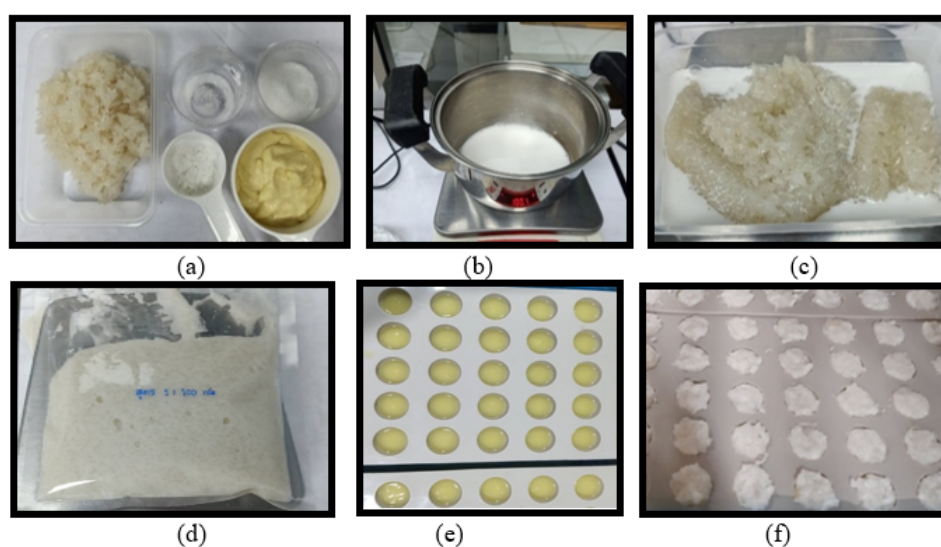


Figure 1. Preparation procedure of durian sticky rice prior to freeze drying: (a) Preparation of ingredients, (b) Preparation of coconut milk at volumes of 100, 150, and 200 mL with added salt and sugar, (c) Mixing glutinous rice with coconut milk followed by coarse blending, (d) Packaging the mixture in plastic bags and refrigerating for 5 hours., (e) Spreading durian purée on top and freezing until solid and (f) Molding the durian sticky rice mixture

Results

Physicochemical properties

The color parameters (L^* , a^* , and b^*) of freeze-dried durian sticky rice with different amount of coconut milk (100, 150 and 200 ml) are shown in Table 1. As there was no significant difference in color value in both durian layer and sticky rice layer between each treatment ($p > 0.05$), the difference in coconut milk

amount has no effect on the stability of the color during the freeze drying. Freeze-dried durian sticky rice is shown in Figure 2.

On the contrary, water activity and moisture content were significantly differed between the treatments ($p \leq 0.05$), as it is shown in Table 2. The higher water activity (0.48) and moisture content (1.91 %) were observed in the sample with 100 ml coconut milk followed by sample with 150 ml coconut milk ($a_w = 0.30$; moisture content=1.62%). Whereas lowest water activity (0.20) and moisture content (1.51%) were found in sample with 200 ml coconut milk. This result indicating that increased concentration of coconut milk would benefit to enhance the residual moisture and water activity lowering of freeze-dried product. Texture analysis, hardness value between treatment were statistically differed ($p \leq 0.05$) (Table 2). The hardness value was highest in the sample with 100 ml coconut milk (287.42 N), and the hardness value for sample with 150 ml coconut milk was 263.62 N and sample with 200 ml coconut milk was 250.81 N. Therefore, higher concentration of coconut milk resulted in softer texture of freeze-dried product. Lower hardness might be related with higher amount of lipid and moisture distribute in the food matrix resulted to alter food structure in the drying process.

Table 1. Color parameters of freeze-dried durian sticky rice formulated with varying coconut milk concentrations

Coconut milk concentration (ml)	Color value					
	L*		a*		b*	
	top (durian)	bottom (sticky rice)	top (durian)	bottom (sticky rice)	top (durian)	bottom (sticky rice)
100	81.68±0.44	84.63±1.54	-3.66±0.17	-0.75±0.06	33.43±1.44	7.67±0.26
150	81.70±0.30	84.53±4.87	-3.66±0.16	-0.75±0.11	32.67±1.19	7.84±0.04
200	81.82±0.59	84.34±2.83	-3.68±0.18	-0.79±0.03	33.10±1.38	7.96±0.29

Note : ^{ns} represents no statistically significant difference ($p > 0.05$)

L* represents lightness, with values ranging from 0 to 100, where 0 indicates black and 100 indicates white

a* represents the color axis from green ($-a^*$) to red ($+a^*$)

b* represents the color axis from blue ($-b^*$) to yellow ($+b^*$)



Figure 2. An example of freeze-dried durian sticky rice

Table 2. Physical quality analysis of freeze-dried durian sticky rice prepared with different coconut milk concentrations

Coconut milk concentration (ml)	Water activity	Moisture (%)	Hardness (N)
100	0.48 ^a	1.91 ^a	287.42 ^a
150	0.30 ^b	1.62 ^b	263.62 ^b
200	0.20 ^c	1.51 ^b	250.81 ^b

Note : ^{abc} Means in the same column with different superscript letters indicate statistically significant differences ($p \leq 0.05$)

Microbiological quality

The result on microbiological quality of freeze-dried durian sticky rice presented in Table 3. Aerobic plate count, yeast, molds and coliform count were found to be in the required standards for Department of Medical sciences for dried foods having water activity < 0.86 .

Sensory evaluation

Results of sensory evaluation for the freeze-dried durian sticky rice with different amounts of coconut milk added were shown in Table 4. The results indicated no significant difference ($p > 0.05$) among all the treatments in terms of appearance, color, odor and texture but significant difference ($p \leq 0.05$) for taste and overall acceptability. Among all the treatments tested, the one with 150 ml of coconut milk scored the highest point for overall acceptability (7.24), while the ones with 100ml and 200 ml gained scores of 6.87 and 6.60 respectively. It is possible to conclude that 150 ml coconut milk gave the best combination for sensory attributes of freeze-dried durian sticky rice. This might be due to the presence of the optimal amount of coconut milk that results in the balanced taste (sweetness), fat content and texture in the matrix.

Table 3. Microbiological analysis of freeze-dried durian sticky rice produced with varying coconut milk concentrations

Type of microorganisms	Reference standard	Microbial count		
		Coconut milk 100 ml	Coconut milk 150 ml	Coconut milk 200 ml
Aerobic Count	Not specified	88000 CFU/g	32000 CFU/g	98000 CFU/g
Coliform	Not specified	> 1100 MPN/g	460 MPN/g	< 1100 MPN/g
<i>Escherichia coli</i>	< 3 CFU/g	< 3 CFU/g	< 3 CFU/g	< 3 CFU/g
<i>Staphylococcus aureus</i>	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g	< 10 CFU/g
Yeast	< 100 CFU/g	< 50 CFU/g	< 60 CFU/g	< 80 CFU/g
Mold	< 100 CFU/g	< 30 CFU/g	< 10 CFU/g	< 60 CFU/g

Note : The reference standard is based on the Notification of the Department of Medical Sciences regarding the microbiological quality criteria for foods and food-contact containers, Edition 3: Dried foods with a water activity (a_w) less than 0.86.

Table 4. Sensory evaluation of freeze-dried durian sticky rice with different coconut milk concentrations

Coconut milk concentration (ml)	Sensory evaluation					
	Appearance ^{ns}	Color ^{ns}	Odor ^{ns}	Taste	Texture ^{ns}	Overall acceptability
100	7.03±1.65	7.13±1.36	7.40±1.63	7.57±1.28 ^a	6.03±2.01	6.87±1.68 ^{ab}
150	7.13±1.36	7.07±1.34	7.20±1.58	7.53±1.57 ^a	6.63±2.27	7.24±1.46 ^a
200	6.73±1.76	6.77±1.60	6.93±1.74	6.73±1.86 ^b	5.97±2.28	6.60±1.77 ^b

Note : ^{abc} Means in the same column with different superscript letters indicate statistically significant differences ($p \leq 0.05$)

^{ns} represents no statistically significant difference ($p > 0.05$)

Yield

The percentage yields after freeze drying the coconut milk varied formulations of durian sticky rice is shown in Table 5. All formulations of durian sticky rice produced a percentage yield greater than 50% after freeze drying. 100 ml coconut milk has produced a percentage yield of 57.91% and 200 ml coconut milk produces a percentage yield of 52.82%. It is shown that higher percentage yield was observed using lower volume of coconut milk. This might be affected the percentage of solid and liquid in the formulations.

Table 5. Yield of freeze-dried durian sticky rice

Coconut milk concentration (ml)	Yield (%)	
	Before freeze dry	After freeze dry
100	99.5	57.91
150	98.2	56.26
200	95.80	52.82

Discussion

In this study, it has been demonstrated that coconut milk concentration had significantly impact on the water activity, moisture content, texture properties, sensory preference and yield of freeze-dried durian sticky rice, however parameters about the color was quite stable under each condition which showed that the concentration of coconut milk had little effect on the color property of the final product after freeze-dried. As for the color value in this study, it has been found that after freeze-dried process, the color value of the product could be remained because the freeze-dried technology could limit the thermal degradation and enzymatic browning reaction occurred in the traditional drying methods at low temperature (Ratti, 2001), and also durian and sticky rice layer can remain close color values to the raw condition. Furthermore, it was also revealed that the color stability of freeze-dried fruit was superior to hot-air dried

system (Wongkhalaung *et al.*, 2021). Water activity and moisture content of the product were decreased with the increasing concentration of coconut milk. It has been observed that the sample with the addition of 200 ml coconut milk had the minimum final residual moisture content and water activity after freeze-dried; the reason may be that changing in food matrix composition means the increasing of proportion of lipid and solid components added to the food matrix when the amount of coconut milk increase, which affects the interaction of water and fat in the system and thus influences water migration and the expulsion of the vapor from the food matrix (Fang *et al.*, 2020). Low water activity is a critical characteristic of the dry food product because it restricts the microbial activity and increase the shelf-life during storage.

Concerning to texture analysis, the hardness value of the dry sticky rice was increased when decreasing in the amount of coconut milk used in the product, softer texture is likely to occur with more coconut milk could be caused by increased fat content. Fat components are able to affect the retrogradation of starch and solid structure formation of dried foods thereby leads to the low density in the final product. Similar observations were found in the food products in other study using starch as a main matrix which the amount of fat can affect texture and mechanical properties (Waritchon and Kunlaporn, 2022).

Microbiological analysis revealed that all freeze-dried durian sticky rice samples met all the requirement criteria on micro biological requirements of low water activity dried food. *E. coli* and *S. aureus* were not detected in any of the treatments. Low moisture content and low water activity on the freeze-dried durian sticky rice could have played an important role in maintaining viability and multiplication of microorganisms, as it is similar to that observed in freeze-dried food that microorganism activity was reduced due to less amount of water for metabolism (Fang *et al.*, 2020). Sensory analysis showed that formula with 150 ml of coconut milk was the most preferred in overall score among the treatments. While no statistically significant difference in appearance, color, odor and texture had been observed from panel score, the taste and overall balanced of the formulation with 150 ml coconut milk was highly desired. Moderate amount of coconut milk is needed to achieve balanced sweetness, flavor, fat, texture and mouth feel.

It can be noticed that different formulation yielded different products. As coconut milk amount was increased, the yield of the freeze-dried product was decreased. The decrease in yield was possibly due to higher liquid and lipid content of the formulation which may influence drying efficiency, consequently leading to lower residual solid content. The results obtained by Lawton *et al.* (2004) reported that solid retention decreased in formulations with high amounts of liquid and solid contents. All in all, the results obtained in this study indicated

that the addition amount of coconut milk had significantly influence on the quality attributes of the freeze-dried durian sticky rice. Between the evaluated coconut milk concentration, the formula of 150 ml coconut milk appears to be the optimal formulation for all physical, texture, and sensory quality as well as micro biological safety, indicating a good potential for commercialized long shelf life thai dessert and distribution to domestic and overseas market. Long term study on storage stability, packaging system, nutritional and bioactive compound retention should be conducted.

Coconut milk concentration was significantly affected on physicochemical and sensory quality of freeze-dried durian sticky rice on the water content, water activity, texture characteristic, acceptance and yield of product, respectively. The freeze-dried durian sticky rice had color that did not change at different coconut milk concentration, the color that formed not affected by the freeze-drying process. The acceptance rate of product added with 150 ml of coconut milk was the highest in the entire formulation and good physicochemical and microbiology quality of product also. It showed the proposed product has good safety on based on the microbiology standard of dried food which water activity was low. It was considered the proposed product with freeze drying was potential to commercialize for durian sticky rice and storage quality, packaging methods, nutritional quality after storage should be studied more for production and marketability.

Acknowledgements

The authors are gratefully to Sunshine International Co., Ltd. For using research facilities and technical support throughout the whole of this research. Many thanks and thanks in sincerity were also given to Ms Kasarin Thangngern, Manager of Food Quality Control Department for her useful instructions and suggestion. At last, thanks were also sincerely appreciated to the cooperative education students, which are Ms. Santhakan Kun-Anek, Ms. Wanwisa Phoyai and Ms. Wiranchana Ritthibut, for supporting this research.

Conflicts of interest

The authors declare no conflicts of interest.

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(Received: 30 September 2025, Revised: 16 June 2026, Accepted: 9 July 2026)