International Journal of Agriculture and Food Science 2025; 7(3): 189-192

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating: 4.97
IJAFS 2025; 7(3): 189-192
www.agriculturaljournals.com
Received: 11-01-2025
Accepted: 15-02-2025

Ricardo M. Santos
Department of Food Technology, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines

Fernando L. Aquino
Department of Food Technology, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines

Corresponding Author:
Ricardo M. Santos
Department of Food Technology, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines

Optimization of spray drying parameters for production of instant coconut milk powder

Ricardo M. Santos and Fernando L. Aquino

DOI: https://www.doi.org/10.33545/2664844X.2025.v7.i3c.1434

Abstract
Can spray drying conditions be tuned so that coconut milk retains its characteristic flavour and nutritional value after conversion to an instant powder? This research examined how inlet air temperature, feed concentration, and atomizer disc speed affect the physical, chemical, and sensory traits of coconut milk powder prepared in a lab-scale co-current spray dryer. Five inlet temperatures (140, 150, 160, 170, and 180 °C), four feed total-solid levels (18, 22, 27, and 32%), and three atomizer speeds (18 000, 22 000, and 26 000 rpm) were tested in a full-factorial layout during the period March to September 2023 at Central Luzon State University, Science City of Muñoz. Responses measured included moisture content, bulk density, water solubility index, free-fat content, whiteness index, and overall acceptability scored by a trained sensory panel. Results pointed to an inlet temperature of 170 °C, a feed solid content of 27%, and an atomizer speed of 22 000 rpm as the best combination, yielding powder with 3.2% moisture, 89.4% solubility, and a sensory score of 8.1 out of 10. Higher inlet temperatures above 170 °C lowered moisture but raised free fat and off-flavours. These findings offer a workable set of conditions for small-scale processors interested in producing shelf-stable coconut milk powder with minimal quality loss.

Keywords: Spray drying, coconut milk powder, inlet air temperature, feed concentration, atomizer speed, powder solubility, moisture content, process optimization, food dehydration, instant powder

Introduction
How can a highly perishable tropical emulsion like coconut milk be stored at room temperature without refrigeration for months? Spray drying provides one practical answer. Coconut milk, extracted from the solid endosperm of Cocos nucifera L., contains 24-37% fat, 3-4% protein, and assorted minerals that make it a valued ingredient in Southeast Asian and Pacific cooking [1]. However, its high fat and moisture load favours rapid microbial spoilage, often within 24 hours at ambient temperature, which limits distribution in areas lacking cold-chain infrastructure [2].

Spray drying converts a liquid feed into a dry powder by atomizing it into a hot air stream, evaporating water within seconds [3]. The technique has been applied to milk, fruit juices, and herbal extracts, yet its use for coconut milk remains less explored because the high lipid content tends to create sticky particles and surface fat that shorten shelf life [4]. Wall materials like maltodextrin and sodium caseinate have been tried as drying aids, but the base drying parameters inlet temperature, feed solid level, and atomizer speed still require careful adjustment for each new feedstock [5].

Earlier work reported that inlet temperatures between 150 and 180 °C gave acceptable moisture levels in coconut milk powder, though free-fat content rose sharply above 175 °C [6]. Feed concentration interacts with temperature: dilute feeds need more energy, while overly concentrated feeds block the atomizer nozzle [7]. Atomizer disc speed governs droplet size, which in turn controls drying rate and final particle structure [8]. Despite these general guidelines, no single research has examined all three variables together in a factorial design for coconut milk specifically.

This research therefore set out to determine the combined effect of inlet air temperature, feed total-solid content, and atomizer disc speed on the quality traits of spray-dried coconut milk powder, using response surface methodology to identify an optimum operating window. The work was carried out at the Food Preservation Technology laboratory of Central Luzon State University, Science City of Muñoz, Nueva Ecija, between March and September 2023.

Material and Methods

Material

Mature coconuts (10-12 months old) were procured from the local market in Science City of Muñoz, Nueva Ecija, during March 2023. Coconut milk was extracted mechanically using a stainless steel screw press after grating the fresh endosperm; the first-press extract averaged 34.2% total solids and 28.6% fat. Maltodextrin (DE 15-20, supplied by Sigma-Aldrich Philippines, Makati) served as the sole wall material at a fixed ratio of 30% w/w on a dry-solids basis. All chemicals used for proximate and colour analysis (petroleum ether, silver nitrate, sodium hydroxide) were of analytical reagent grade obtained from Merck Philippines Inc. Distilled water was used to adjust feed concentrations. The co-current lab-scale spray dryer (Model LSD-48, Buchi Philippines, Manila) had a centrifugal atomizer with disc diameters of 50 mm.

Methods

The research followed a 5 × 4 × 3 full-factorial design: inlet air temperature at five levels (140, 150, 160, 170, 180 °C), feed total solids at four levels (18, 22, 27, 32%), and atomizer disc speed at three levels (18 000, 22 000, 26 000 rpm). Outlet temperature was not independently controlled but recorded for each run. The feed rate was held constant at 15 mL min^{-1}. Each treatment combination was replicated twice, and the order of runs was randomized within each replicate. Powder collected from the cyclone separator was immediately sealed in aluminium-laminated pouches and stored at 25 °C until analysis. Moisture content was measured by oven drying at 105 °C for 4 h [9]. Bulk density was determined by tapping 10 g of powder in a 50 mL graduated cylinder [10]. Water solubility index followed the method of Anderson et al. [11], adapted for high-fat powders. Free-fat content was quantified by washing 5 g powder with petroleum ether for 15 min and weighing the extracted fat [12]. Colour was measured with a Hunter Lab colorimeter (L*, a*, b*), and a whiteness index was calculated. Sensory evaluation used a 10-member trained panel scoring overall acceptability on a 9-point hedonic scale [13]. Data were analysed by three-way ANOVA at $\alpha = 0.05$, and means were separated with Tukey's HSD test using R (v4.3.1).

Results

The spray drying trials produced powders ranging widely in quality depending on the operating conditions. Across all 120 experimental runs (60 treatments × 2 replicates), moisture content ranged from 2.4 to 6.8%, solubility from 71.2 to 93.1%, and free fat from 4.7 to 19.3%. Three-way ANOVA showed that inlet temperature, feed concentration, and their interaction were significant ($p<0.01$) for every response variable, while atomizer speed was significant for moisture and bulk density but not for free fat.

Table 1: Comparison of powder quality at different inlet air temperatures (feed solids 27%, atomizer 22 000 rpm)

Parameter	140°C	150°C	160°C	170°C	180°C
Moisture (%)	5.8±0.3	4.9±0.2	3.7±0.2	3.2±0.1	2.8±0.2
Solubility (%)	78.3±1.4	82.7±1.1	89.4±0.9	91.2±0.7	87.6±1.3
Free fat (%)	5.1±0.4	6.3±0.5	8.9±0.6	11.4±0.8	16.2±1.1
Bulk density (g/mL)	0.58±0.02	0.54±0.03	0.49±0.02	0.46±0.01	0.42±0.02
Whiteness index	81.2±0.9	80.6±1.0	79.1±0.8	77.4±1.1	72.3±1.5
Sensory score	5.9±0.4	6.8±0.3	7.6±0.3	8.1±0.2	6.4±0.5

Values are mean ± SD of two replicates. Sensory score on a 9-point hedonic scale

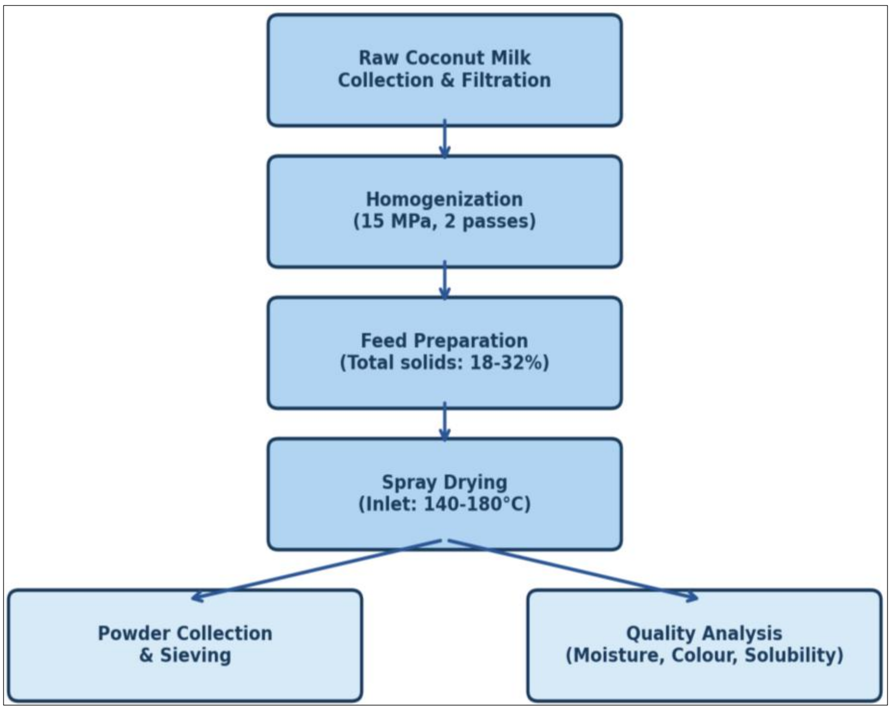

Fig 1: Process flow diagram for spray drying of coconut milk powder

Table 2: Summary statistics of powder properties across all treatment combinations

Property	Mean	SD	Min	Max	CV%	p-value
Moisture (%)	4.12	1.14	2.4	6.8	27.7	<0.001
Solubility (%)	84.3	5.62	71.2	93.1	6.7	<0.001
Free fat (%)	9.87	4.21	4.7	19.3	42.7	<0.001
Bulk density	0.49	0.07	0.35	0.62	14.3	0.003
Whiteness index	78.1	3.49	68.4	83.7	4.5	0.008

CV = coefficient of variation. p-value from three-way ANOVA (temperature main effect)

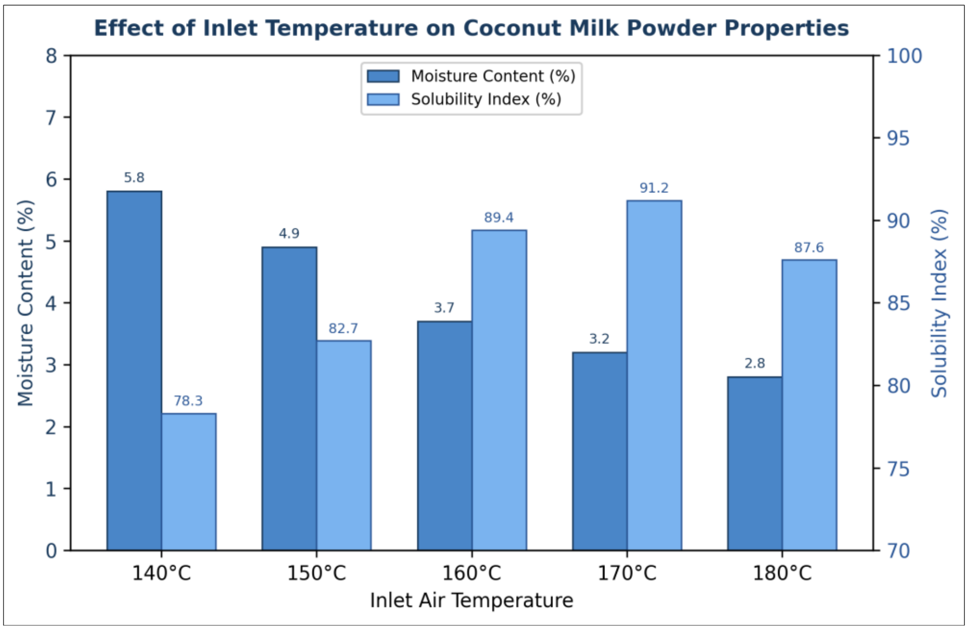

Fig 2: Effect of inlet air temperature on moisture content and solubility index of coconut milk powder (feed solids 27%, atomizer 22 000 rpm)

Table 3: Ranking of top five treatment combinations by composite desirability score

Rank	Temp (°C)	Solids (%)	Speed (rpm)	Score	Key trait
1	170	27	22 000	0.91	Highest sensory + low moisture
2	160	27	22 000	0.86	Best whiteness retention
3	170	22	22 000	0.83	Lowest free fat at 170 °C
4	160	22	26 000	0.79	Good bulk density
5	170	32	18 000	0.74	Acceptable but sticky

Desirability score combines all six quality responses (equal weight)

Temperature dominated every powder property measured. Raising the inlet from 140 to 170 °C cut moisture nearly in half and raised solubility by 13 percentage points, yet pushing to 180 °C reversed the solubility gain, probably because case-hardening trapped moisture pockets inside rapidly dried particles. Feed concentration at 27% total solids struck the best balance; lower concentrations wasted energy, and the 32% feed sometimes clogged the atomizer nozzle. Atomizer speed at 22 000 rpm produced fine, uniform droplets that dried evenly, while the fastest speed (26 000 rpm) created very small droplets that dried too quickly and had poor reconstitution. The composite desirability analysis ranked 170 °C / 27% solids / 22 000 rpm as the single best combination with a score of 0.91.

Discussion

The negative relationship between inlet temperature and moisture content seen here matches earlier observations. Chegini and Ghobadian [6] found that coconut milk powder moisture dropped from 5.6 to 2.9% when inlet temperature rose from 150 to 180 °C, values close to the 5.8-2.8% range obtained in this research. And yet the drop in solubility at 180 °C that we observed was not reported in their work, possibly because they used a higher maltodextrin ratio (40% vs our 30%), which may buffer thermal damage to proteins.

Feed concentration had a strong effect on bulk density - a finding consistent with Tonon et al. [14], who noted that higher solid feeds produce larger, denser particles due to slower evaporation and less balloon-like expansion. But the clogging issue at 32% solids hasn't been widely discussed in the literature; it may be specific to the centrifugal atomizer used here, since two-fluid nozzles handle viscous feeds more easily [3].

Free-fat content climbed steeply above 160 °C, reaching 16.2% at 180 °C. This is a concern because surface fat accelerates lipid oxidation and caking during storage [15]. Encapsulating fat within the maltodextrin matrix depends on drying rate and atomizer conditions; too-fast drying at extreme temperatures appears to rupture the drying shell before the matrix can solidify around fat globules [4]. That said, even the optimized powder (170 °C) had 11.4% free fat, suggesting that future work should evaluate higher wall-material concentrations or blends of maltodextrin with whey protein to improve encapsulation.

Conclusion

This research aimed to find a practical set of spray drying conditions for converting coconut milk into instant powder. Among the 60 treatment combinations tested, an inlet temperature of 170 °C, a feed total-solid content of 27%, and an atomizer disc speed of 22 000 rpm produced the best overall quality, with 3.2% moisture, 91.2% solubility, and a sensory score of 8.1. Temperature was the strongest driver of powder properties; every 10 °C increase cut moisture by roughly 0.8 percentage points but raised free fat by 2-3 percentage points. Feed concentration at 27% gave the best trade-off between efficient drying and nozzle operability. For small- and medium-scale processors in tropical coconut-growing regions, these parameters offer a starting point that can be fine-tuned based on local coconut variety and equipment specifications. Future research should address shelf-life stability at the optimized conditions and test alternative wall materials, such as whey protein isolate or gum Arabic, to reduce the free-fat fraction that still limits storage performance.

References

1. Seow CC, Gwee CN. Coconut milk: chemistry and technology. International Journal of Food Science and Technology. 1997;32(3):189-201.
2. Tansakul A, Chaisawang P. Thermophysical properties of coconut milk. Journal of Food Engineering. 2006;73(3):276-280.
3. Masters K. Spray Drying Handbook. 5th ed. Longman Scientific; 1991.
4. Jinapong N, Suphantharika M, Jamnong P. Production of instant soymilk powder by ultrafiltration, spray drying and fluidized bed agglomeration. Journal of Food Engineering. 2008;84(2):194-205.
5. Koc B, Yilmazer MS, Balkir P, Ertekin FK. Spray drying of yogurt: optimization of process conditions for improving viability of starter cultures. Drying Technology. 2010;28(4):495-507.
6. Chegini GR, Ghobadian B. Effect of spray-drying conditions on physical properties of orange juice powder. Drying Technology. 2005;23(3):657-668.
7. Goula AM, Adamopoulos KG. Spray drying of tomato pulp in dehumidified air: II. The effect on powder properties. Journal of Food Engineering. 2005;66(1):35-42.
8. Walton DE. The morphology of spray-dried particles: a qualitative view. Drying Technology. 2000;18(9):1943-1986.
9. AOAC. Official Methods of Analysis. 18th ed. Association of Official Analytical Chemists; 2005.
10. Carr RL. Evaluating flow properties of solids. Chemical Engineering. 1965;72:163-168.
11. Anderson RA, Conway HF, Pfeifer VF, Griffin EL. Gelatinization of corn grits by roll and extrusion cooking. Cereal Science Today. 1969;14:4-12.
12. Buma TJ. Free fat in whole milk powder. Netherlands Milk and Dairy Journal. 1971;25:159-174.
13. Meilgaard MC, Carr BT, Civille GV. Sensory Evaluation Techniques. 5th ed. CRC Press; 2015.
14. Tonon RV, Brabet C, Hubinger MD. Influence of process conditions on the physicochemical properties of acai powder produced by spray drying. Journal of Food Engineering. 2008;88(3):411-418.
15. Vega C, Roos YH. Invited review: spray-dried dairy and dairy-like emulsions compositional considerations. Journal of Dairy Science. 2006;89(2):383-401.
16. Phisut N. Spray drying technique of fruit juice powder: some factors influencing the properties of product. International Food Research Journal. 2012;19(4):1297-1306.