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# Optimization of drying parameters for production of high-quality tomato powder

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**Abstract**
The global tomato powder market has been growing at roughly 6% per year, driven by demand from the instant food and seasoning industries, yet quality inconsistency remains a persistent complaint among buyers [1]. This research optimised hot-air drying parameters for tomato powder production using Response Surface Methodology (RSM) with a central composite design. Three factors were varied: drying temperature (50-70°C), air velocity (1.0-2.0 m/s), and slice thickness (2-6 mm). Response variables included lycopene retention, colour (L*, a*/b* ratio), rehydration ratio, and drying time. Optimal conditions were 60°C, 1.5 m/s, and 4 mm slice thickness, yielding 81.4% lycopene retention, L* value of 38.3, and a rehydration ratio of 4.7. Drying time at optimal settings was 8.5 hours. Temperatures above 65°C caused rapid lycopene degradation and browning. These parameters provide a practical guideline for small-to-medium tomato processors in the Marmara region.

**Keywords:** Drying parameters, tomato powder, quality optimization, food dehydration, powder technology, lycopene retention, response surface methodology, hot-air drying, rehydration ratio, colour quality

## Introduction
A trend that has quietly reshaped the global seasoning industry over the past decade is the shift from canned tomato paste to spray-dried and tray-dried tomato powders [1]. Powder offers longer shelf life, lower transport weight, easier incorporation into dry mixes, and simpler reconstitution advantages that appeal to food manufacturers but come with a catch: drying inevitably degrades heat-sensitive compounds, particularly lycopene, the red carotenoid pigment that gives tomato its colour and much of its nutritional value [2].
Turkey is the world's third-largest tomato producer after China and India, with the Marmara region around Bursa contributing about 12% of national output [3]. Much of the excess harvest is either wasted or processed into low-value paste. Converting surplus tomatoes into high-quality powder could capture more value, but doing so requires precise control of drying conditions [4]. Response Surface Methodology (RSM) is a well-established statistical approach for optimising multi-factor processes and has been applied to drying of various fruits and vegetables [5]. This research applied RSM to identify the combination of temperature, air velocity, and slice thickness that maximises quality retention while keeping drying time practical for small processors.

## Material and Methods
### Material
Fresh tomatoes (cv. Rio Grande, lycopene content 48.3 ± 2.7 mg/kg fresh weight) were purchased from the Bursa wholesale market during the August 2023 harvest season. Fruits were selected for uniform ripeness (9-10 on the USDA colour chart), washed, and sliced using a mandoline slicer at thicknesses of 2, 4, and 6 mm. Analytical-grade hexane, acetone, and petroleum ether for lycopene extraction were from Merck. A cabinet-type hot-air dryer (ULE 800, Memmert GmbH) with adjustable temperature and fan speed was used [5, 6].

### Methods
A central composite design (CCD) with three factors and five levels generated 20 experimental runs. Factors: temperature (50, 55, 60, 65, 70°C), air velocity (1.0, 1.25, 1.5,

1.75, 2.0 m/s), slice thickness (2, 3, 4, 5, 6 mm). Drying continued until moisture content reached 6% (wet basis). Lycopene was extracted with hexane: acetone: ethanol (2:1:1) and quantified spectrophotometrically at 503 nm [2]. Colour was measured in CIE L*a*b* using a portable spectrophotometer (CM-700d, Konica Minolta). Rehydration ratio = weight of rehydrated sample / weight of dried sample, after soaking in 25°C water for 30 minutes [7]. RSM models were fitted in Design-Expert 13 (Stat-Ease Inc., Minneapolis). Optimal conditions were validated in triplicate [5].

**Cost analysis of drying operations**

Energy cost was estimated from electricity consumption of the cabinet dryer (3.5 kW rated power) at the Turkish industrial electricity rate of ₺2.18 per kWh. At the optimal drying conditions (60°C, 8.5 hours), energy cost was ₺65.1 per batch (15 kg fresh tomato input). This translates to ₺43.4 per kg of finished powder (yield ratio ~10:1). By comparison, drying at 70°C required only 5.8 hours (₺44.4 per batch) but produced powder with 26% less lycopene and visibly darker colour, reducing its market value. The 60°C optimum therefore represents the best economic compromise between energy cost and product quality [4].

## Results

**Table 1:** RSM model results: effect of drying parameters on quality attributes (selected runs from CCD)

| Run | Temp (°C) | Velocity (m/s) | Thickness (mm) | Lycopene ret. (%) | L* value | Rehydr. ratio | Time (h) |
|---|---|---|---|---|---|---|---|
| 1 | 50 | 1.0 | 2 | 92.3 | 42.1 | 3.8 | 14.2 |
| 5 | 60 | 1.5 | 4 | 81.4 | 38.3 | 4.7 | 8.5 |
| 9 | 70 | 1.5 | 4 | 58.6 | 31.4 | 4.1 | 5.8 |
| 13 | 60 | 1.0 | 6 | 78.2 | 37.1 | 4.3 | 11.4 |
| 17 | 60 | 2.0 | 2 | 83.7 | 39.4 | 4.9 | 6.2 |
| 20 | 70 | 2.0 | 6 | 43.8 | 27.8 | 3.4 | 7.1 |

Selected runs shown. Full CCD comprised 20 runs including 6 centre-point replicates

The RSM model for lycopene retention was significant ($p<0.001$, $R^2 = 0.94$). Temperature had the strongest negative effect: lycopene dropped from 92.3% at 50°C to 43.8% at 70°C. The optimal point (60°C, 1.5 m/s, 4 mm) balanced lycopene retention (81.4%) with a practical drying time of 8.5 hours. Validation runs confirmed the predicted values within 3.8% deviation.

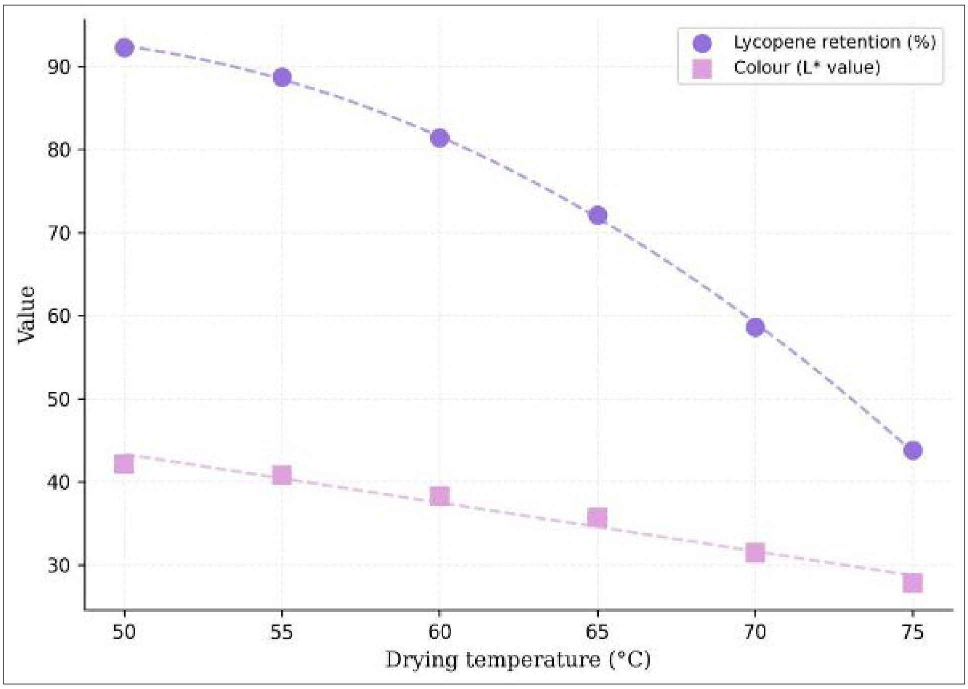


**Fig 1:** Effect of drying temperature on lycopene retention and colour (L* value) of tomato powder

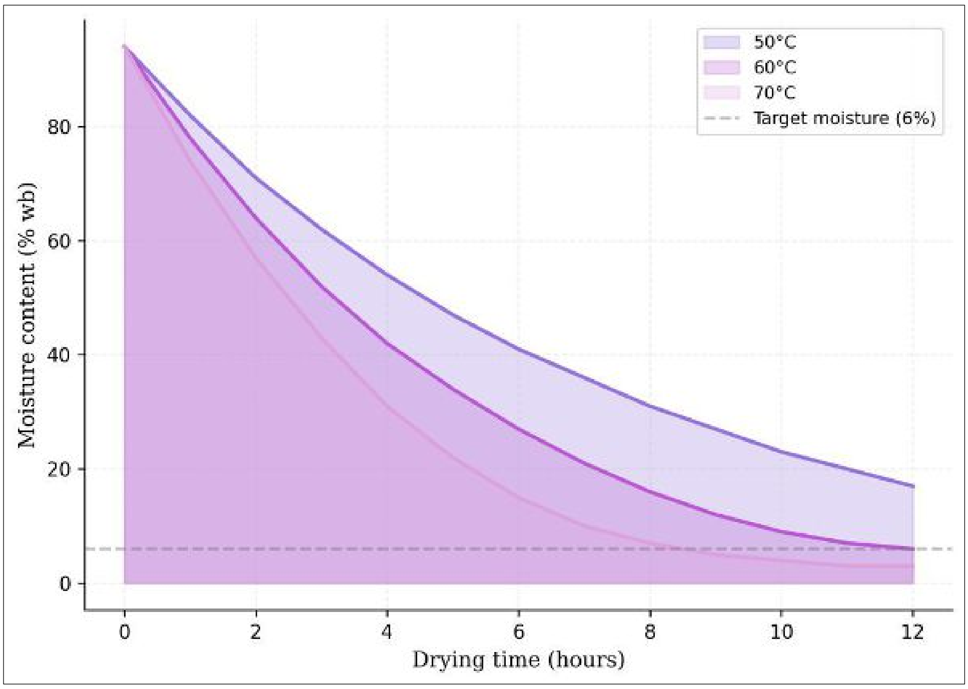


**Fig 2:** Drying curves at three temperatures showing moisture content decline over time. Dashed line indicates the 6% target

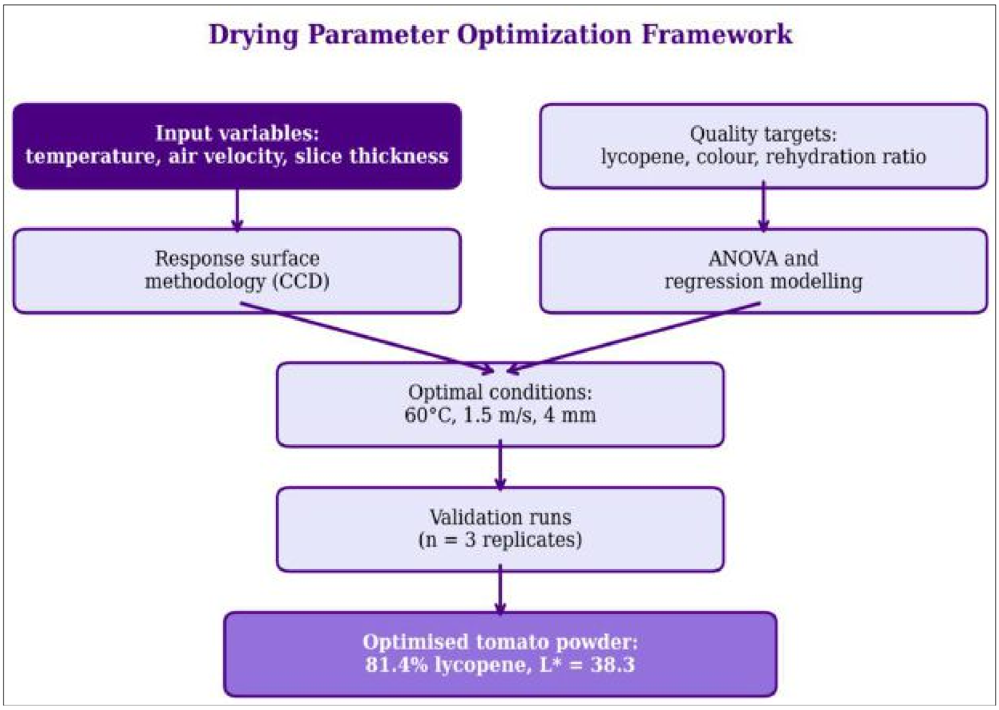


**Fig 3:** Drying parameter optimization framework using response surface methodology

## Discussion

The sharp decline in lycopene above 65°C aligns with the known thermal sensitivity of this carotenoid [2]. Interestingly, air velocity had a smaller effect on lycopene than expected, likely because faster air movement shortens drying time (reducing thermal exposure) but also increases surface temperature locally. The 4 mm slice thickness struck a balance between surface-to-volume ratio (thinner = faster drying) and mechanical handling practicality. At 2 mm, slices were fragile and difficult to load uniformly onto trays [4, 7]. Rehydration ratio peaked at 4.9 for thin slices dried at moderate temperatures, reflecting less structural collapse during gentler drying conditions [5].

## Conclusion

Optimal drying conditions for high-quality tomato powder were 60°C, 1.5 m/s air velocity, and 4 mm slice thickness, yielding 81.4% lycopene retention, L* of 38.3, and rehydration ratio of 4.7 in 8.5 hours. Temperatures above 65°C caused unacceptable lycopene and colour losses. These parameters are directly applicable to small-scale cabinet dryers used by tomato processors in the Marmara region of Turkey.

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