

UNIVERSITI TEKNOLOGI MARA

**PRODUCTION OF PINEAPPLE
CENTELLA ASIATICA L. (PCAL)
POWDER BY SPRAY DRYING
PROCESS: OPTIMIZATION,
MODELLING, AND
ENCAPSULATION MECHANISM**

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ABSTRACT

Spray drying of pineapple poses significant challenges due to its high sugar content and stickiness, resulting in low powder yield and poor handling properties. To address these limitations, this study explores the application of antioxidant rich *Centella asiatica* L. (CAL) as a natural bioactive additive and stabiliser, reducing sugar related stickiness and supporting production of higher yield, nutritionally enriched spray dried powders. This study aimed to evaluate spray drying conditions for optimizing pineapple *Centella asiatica* L. (PCAL) powder, investigating its drying kinetics, physicochemical properties, moisture sorption behaviour, and bioactive encapsulation mechanism. The process variables identified were inlet temperature (130 – 170 °C), feed flow rate (5 – 10 mL/min), CAL concentrations (3 – 5 %) and maltodextrin concentrations (15 – 30 %). PCAL powder was successfully produced at optimized spray drying conditions of 150 °C inlet temperature, 5 % CAL concentration, and feed flow rate 7.44 mL/min with 20 % (w/v) maltodextrin, producing 77 % powder with a moisture content of 4.18 ± 0.07 % (db). Drying kinetics modelling was evaluated using Diffusion, Henderson & Pabis, Logarithm, Midili, and Newton models, with Midili model providing the best fit. First Order Plus Time Delay (FOPTD) model captured PCAL drying behaviour, with a process gain (K) of 0.4466, time delay (T_d) of 6 minutes, and time constant (t) 6.48 minutes, indicating slower heat transfer and moisture removal. PCAL powder exhibited favourable physicochemical properties, including moisture content below 5 %, high solubility (81.61 ± 0.80 %), moderate hygroscopicity (16.53 ± 0.13 g/100 g), and a glass transition temperature ~ 110 °C, indicating reduced stickiness and improved storage stability. It possessed suitable bulk density (0.437 g/mL) and good flowability (Carr's Index 16.31 %, Hausner Ratio 1.195). Visually, PCAL appeared lighter and more yellow, enhancing its appeal. Peleg model best described moisture sorption behaviour with net q_{st} of 34.4 kJ/mol and Gibbs energy (ΔG) + 0.9759 kJ/mol, classifying the reaction as enthalpy driven with superior resistance to stickiness. FTIR analysis validated successful incorporation of CAL bioactive in spray dried pineapple, while SEM micrographs revealed smooth microcapsules and structural stability. Encapsulation studies confirmed effective retention of CAL bioactive with encapsulation efficiency (EE) and loading efficiency (LE) above 70 %. This study reduced dependency on maltodextrin, pioneered CAL as a natural carrier, and enhanced pineapple spray drying efficiency (~ 75 %) with improved product stability.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Pineapple, a tropical plant, warm-season, and a perennial fruit, belongs to *Bromeliaceae* family, has been cultivated for centuries and grown commercially in extensive plantations. Malaysia has significantly expanded pineapple cultivation, increasing production to meet both domestic and international demand. Currently, 95 % of canned pineapple production is allocated for export markets, with only 5 % catering to domestic consumption. Conversely, fresh pineapple contributes 30 % to export markets while the remaining 70 % is consumed locally. As of year 2022, Malaysia ranked as 22nd most important fresh pineapple exporter globally and 3rd among ASEAN countries, followed with Philippines and Thailand according to Malaysian Pineapple Industrial Board (MPIB). Over past five years, pineapple production in Malaysia experienced a declining trend from 2018 to 2020, averaging 359,751 metric tons annually, a reduction of 15.5 % over three years (Laporan Tahunan 2020, MIPB). However, pineapple production rebounded from 2020 onwards, reaching 537,231 metric tons in 2022, reflecting a substantial 43.1 % increased as compared to 2021 as illustrated in Figure 1.1.

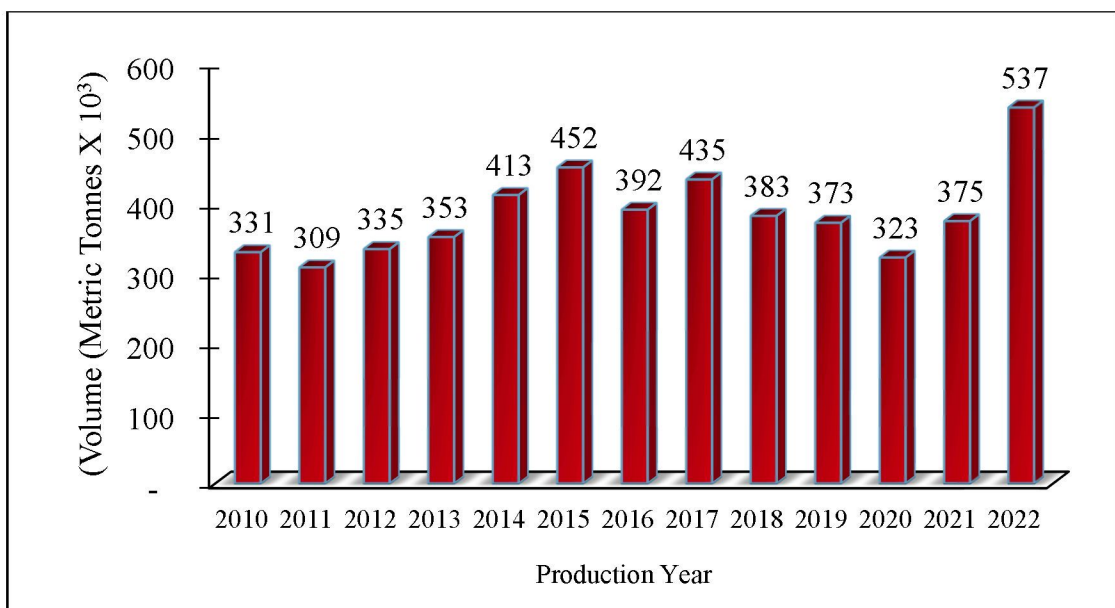


Figure 1.1 Pineapple Production in Malaysia (2010-2022)