Effect of tray drying temperature and drying time on properties of cricket powder

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Abstract. This research studied the production of cricket powder via tray drying and powdering processes by investigating the effect of drying temperature of 80, 90, 100oC and drying time ranging of 30 - 240 min on the properties of cricket powder. The drying rate increased while the moisture content decreased as drying temperature and drying time increased causing it easy to be ground and had good solubility. The cricket powder had dark brown color and its lightness decreased with increasing drying temperature. The produced cricket powder could reach equilibrium moisture content of approximately 5% and the water activity was decreased with increasing drying temperature. Regarding the nutrient content, the change in drying temperature in a range of 80-100oC had no significant effect on the nutrient content. The suitable drying condition of crickets offering the highest protein content of 70.35% was achieved at drying temperature of 80oC and drying time of 240 min. At this condition, 55.57% yield of cricket powder satisfying dry food specification (moisture content of 5.32% and aw of 0.3539) was obtained.

1 Introduction

Global population growth is expected to continue, with estimates of 8.6 billion people by 2030 and 9.8 billion by 2050 [1]. This has led to a rise in both the need for food and animal protein. As a result, it is necessary to expand animal production, which uses a lot of resources including electricity, water, and chemicals. Water and agricultural land are thus insufficient [2]. Additionally, the rise in cattle production contributes significantly to greenhouse gas emissions and other issues related to climate change. Finding innovative methods to produce high-quality protein is an intriguing task in trying to alleviate these issues. Due to the abundance of insects and their low resource consumption during cultivation, producing protein from them is becoming a popular and environmentally benign option [3]. According to Van Huis and Oonincx (2017) [4], the main environmental advantages of insect farming over livestock production were: less land and water needed; lower greenhouse gas emissions; high feed conversion efficiencies; the ability of insects to turn low-value organic byproducts into high-quality food; and the potential for certain insect species to be used as animal or aqua feed.

Because of their high nutritional content, crickets have been introduced as an alternate source of animal protein. The field crickets (Gryllus bimaculatus) had a protein and fat level of 60.7% and 23.4%, respectively, whereas the house crickets (Acheta domesticus) had a protein and fat content of roughly 71.7% and 10%, respectively [5]. Additionally, a number of beneficial elements, including folic acid, riboflavin, tocopherols, magnesium, sodium, potassium, phosphorus, calcium, and vitamin B12, were all found in good amounts in crickets [6]. In the study conducted by Montowska et al. [7], the nutritional value of protein and peptide composition in edible cricket powder was examined. It was discovered that crickets were rich in nutritional components such as protein (55-60%), fat (24-29%), fiber (3.5%-7%), and minerals. The mineral content in 100 g of cricket powder included Ca (139-218 mg), K (826-1224 mg), Mg (86-113 mg), Na (263-312 mg), Cu (2.33-4.51 mg), Fe (4.06-5.99 mg), Mn (4.1-12.5 mg), and Zn (12.8-21.8 mg). Despite the fact that cooked crickets can be consumed directly, there are still some concerns about the image. Additionally, they can spoil if not consumed promptly. Therefore, processing crickets into powder form not only eliminates these image concerns but also adds value to the raw crickets.

Drying, also known as dehydration, is considered the most effective method for preserving food as it reduces the moisture content, which in turn slows down various microbiological and chemical processes occurring in the food [8-10]. The dried powder that is produced becomes a significant raw material for many processed ready-to-eat food products. The combination of drying and powdering is deemed the optimal approach for producing cricket powder. This powdered form of dried crickets serves as a crucial ingredient for numerous processed ready-to-eat food items. Cricket powder is anticipated to play a key role in the health food industry, being used in the production of cricket flour, baked

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chips, protein bars, and snacks [11]. A study conducted by Machado et al. (2019) [12] explored the use of cricket powder, lentil, and buckwheat flours as protein sources in gluten-free bread. The findings revealed that utilizing cricket powder enhanced the quality of the gluten-free bread, ensuring it met technological standards and contained high levels of protein.

Various methods were utilized to dry crickets, such as freeze drying, microwave drying, and hot air drying. Bawa et al. (2020) [13] conducted a study on the effects of hot air and microwave drying on the color, microbiological content, and nutrients of cricket powder. They discovered that there was not a significant difference in the results of the proximate analysis between the two drying methods. Microwave drying was determined to be the most suitable method for producing cricket powder due to its high mineral levels, low microbiological contamination, and improved color compared to hot air drying. Lee et al. (2020) [14] investigated the impact of different drying methods, including hot air drying and freeze drying, on the quality of cricket powder during shortage-term storage. The freeze-dried powder exhibited superior water absorption capabilities compared to the hot air-dried powder, while both samples had similar color and pH. Khammeethong et al. (2024) [15] assessed the effect of tray drying and microwave vacuum drying on the allergenic properties of proteins derived from crickets. It was observed that heat-labile allergens were more susceptible to thermal processing, resulting in decreased antibody binding, especially with tray drying. Psarianos et al. (2024) examined the use of electrohydrodynamic (EHD) drying with and without pulsed electric fields (PEF) pretreatment on house crickets. They determined that combining PEF treatment with conventional oven drying could reduce energy consumption during the drying process and improve protein solubility and antioxidant activity in the final product.

Previously, several works considered the influence of drying methods i.e., microwave, freeze drying and hot air oven on the properties of the cricket powder. However, the microwave, freeze drying methods were complicate and had high operating costs and the oven drying. Therefore, searching for a non-complicated drying method, which has low operating cost, will be another challenge that could enhance the competitiveness of the cricket powder. Among several drying methods, tray drying seems to be a good option due to its simplicity and offers better drying efficiency than oven drying. The purpose of this study is to examine the cricket powder production through the tray drying and powdering processes. The effects of variation in drying temperature (ranging 80-100 °C) and drying time (ranging 30-240 min) on the physical properties of the product are studied. Moreover, the chemical properties in term of nutritional value of the cricket powder prepared from different drying conditions are determined. Finally, the suitable drying condition offering the highest nutritional value and satisfying the criteria of dried food product is presented.

2 Methodology

2.1 Material

Black field cricket (*Teleogryllus commodus*) from the well-known farm in Chonburi, Thailand (Fig. 1). Crickets between 15 days old were used. The 100 g of raw crickets were washed thoroughly with flowing water for approximately 1-2 min. After that, it was blanched to inhibit the activity of enzyme in the crickets using hot water in 3-layer stainless steel autoclave for 5 min to inhibit the activity of enzymes in the insects, then let it dry on a wire rack.

Fig. 1. The 15 days old Black field cricket.

2.2 Tray drying method

A laboratory-model tray dryer identified as Patch/663 was employed for conducting the drying experiments. This dryer included a drying chamber wherein perforated trays, consisting of 10 trays spaced 10 cm apart from each other with each tray measuring 60 cm x 80 cm (equivalent to a surface area of 48 m2), were positioned vertically and horizontally. The trays were arranged in such a way as to fit snugly within the chamber to prevent any air leakage. Heating elements were situated in a plenum chamber, and the raw crickets were evenly spread on the trays before hot air, the heating medium, was circulated through them. The drying process was carried out at three distinct air temperatures: 80, 90, and 100 °C. The components of the laboratory-model tray dryer are illustrated in Figure 2. After attaining the desired drying temperature, 100 g of raw crickets were evenly distributed on the trays in a single layer, as depicted in Figure 3. The tray was then extracted from the dryer, and the moisture content of the crickets was monitored at 30-minute intervals using a moisture analyzer (moisture halogen mettle Toledo HX204) until equilibrium moisture content of roughly 5% was attained. The dried crickets were subsequently ground into small particles and subjected to sieving using test equipment for sieve analysis. The cricket powder that remained on the metal sieve, US standard 120 mesh (125 micron), was collected as samples for further examination.

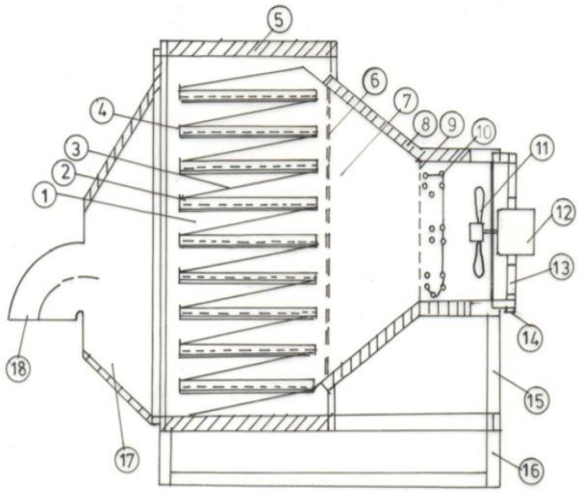

Fig. 2. Laboratory-model tray dryer (1). Drying chamber (2). Tray (3). Baffle plate (4). Tray support platform (5). Insulated drying cabinet wall (6). Perforated plate (7). Inlet air duct (8). Insulated air duct wall (9). Air inlet perforated plate (10). Heating elements (11). Air supply fan (12). Fan drive motor (13). Motor mounting (14). Motor mounting support frame (15). Tool frame (16). Dryer mounting (17). Dryer door (18). Exhaust air outlet [17].

Fig. 3. The crickets were loaded on the tray dryer.

2.3 Analytical methods

The drying rate of cricket was firstly determined. Then the prepared cricket powder was analyzed to examine the characteristic in term of solubility, color, moisture content, water activity, and proximate analysis.

2.3.1 Drying rate

The drying rate was a measure of the ability to evaporate water per time. The drying rate (V) of cricket in tray dryer was calculated from Eq. 1. Where x_1 and x_2 were the moisture content at time t_1 and t_2, respectively.

$$V = \frac{x_1 - x_2}{t_1 - t_2} \tag{1}$$

2.3.2 Solubility

The water solubility of cricket powder was conducted using the methodology described in the existing literature [18]. Specifically, 30 ml of water was poured into a 50 ml beaker, followed by the addition of 3 g of cricket powder. The resulting suspensions were then heated at 30°C on a hot plate for a duration of 3 minutes and subsequently allowed to cool for 15 minutes. Subsequently, the suspensions were transferred to a centrifuge tube and centrifuged at 600 rpm for 5 minutes using an Eppendorf 5920R centrifuge. The supernatant, measuring 20 mL, was collected and transferred to pre-weighed evaporating dishes, which were then subjected to drying at 105°C for 5 hours in an oven dryer. The solubility percentage was determined using the formula specified in Eq. 2.

$$Solubility(\%) = \frac{w_1}{w_0} \times 100 \tag{2}$$

Where w_o is the weight of the dried sample (3 g) and w_1 is the weight of the dried supernatant (g).

2.3.3 Color analysis

The color of prepared cricket powder was analyzed and expressed as L*, a*, and b* value in CEI system using colorimeter (Minolta cr-400). Where L* means brightness value, ranging from 0 (black) to 100 (white). +a* means redness value and -a* means greenness value. +b* means yellowness value and -b* means blueness value.

2.3.4 Moisture content and water activity analysis

In this study, the moisture content and water activity (aw) of prepared cricket power were analyzed. The moisture content was measured using moisture analyzer (moisture halogen mettle Toledo HX204). And the aw was analyzed using a water activity meter (AquaLab, 4TE) which the measure scale was in a range of 0-1.

2.4 Statistical analysis

Each experimental datas were statistically performed in completely randomized design (CRD) with three replicates and analysed by the SPSS statistics program Version 20 (SPSS Institute, USA). The statistical significance of differences between samples was accepted with confidence at 95% ($p>0.05$).

2.4.1 Proximate analysis

The proximate analysis (crude protein, crude fat, ash and moisture) of the cricket powder was performed based on the Association of Official Analytical Chemists (AOAC) official procedure [19]. The percentage of carbohydrate could be calculated as the difference.

3 Results and discussions

In this study the effect of drying temperature (80, 90 and 100ºC) and drying time (30-240 min) on the physical properties, including appearance, color, moisture content and solubility, and chemical properties, in term of nutritional value, of the prepared cricket powder was investigated. And the discussions were shown in the following sections.

3.1 Effect of drying temperature

The impact of different drying temperatures on the moisture levels of crickets was investigated by varying temperatures of 80, 90, and 100 ºC. The results depicted in Figure 4 revealed that when the drying time remained constant, the moisture content of the crickets decreased as the drying temperature increased. This was attributed to the significant temperature difference between the hot air and the crickets, leading to improved heat transfer. As illustrated in Figure 5, this increased the drying rate, facilitating the evaporation of large quantities of water from the crickets.

3.2 Effect of drying time

The impact of drying time within the range of 30-240 minutes was analyzed at varying drying temperatures. It was observed in Figure 4 that, at each drying temperature, the moisture content of crickets exhibited a significant reduction as the drying time decreased between 0 to 180 minutes, owing to the increase in drying rate as illustrated in Figure 5. These findings were consistent with previous studies [20]. Subsequently, the moisture content remained stable at an equilibrium level of approximately 5% when the drying time exceeded this range. Faster attainment of the equilibrium moisture content in cricket powder was observed with higher drying temperatures. It should be noted that the drying temperature did not have an impact on moisture content when the drying time exceeded 210 minutes.

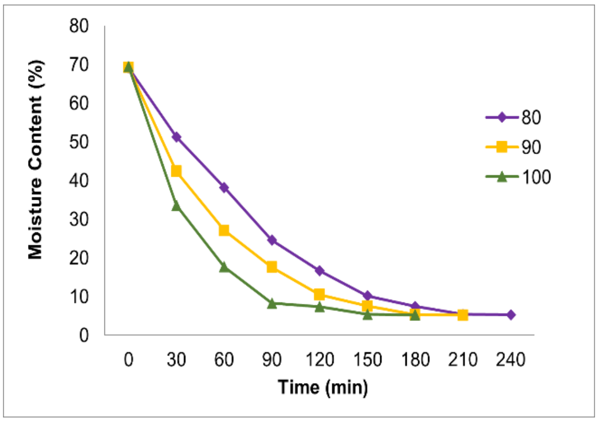

Fig. 4. Drying curve of cricket in tray dryer.

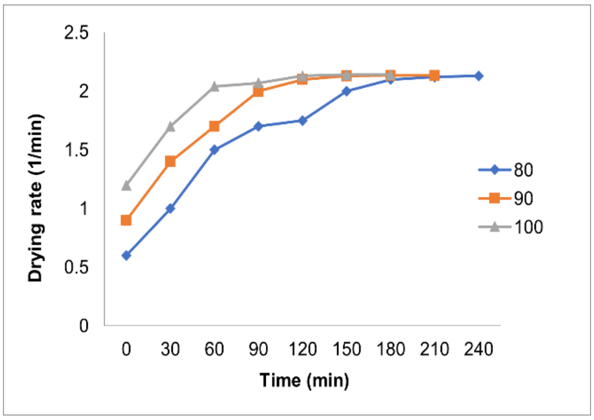

Fig. 5. Drying rate curve of cricket in tray dryer.

3.3 Characteristic of dried cricket powder

The color of cricket powder was analyzed using colorimeter (Minolta cr-400). Average color of cricket powder prepared from crickets drying at various temperatures were shown in Table 1. The samples of cricket power were getting darker as L* value decreased as drying temperature increased. Moreover, a decreased in a* and b* values when drying temperature increased indicated that the sample tending to red and yellow color, respectively. Appearance of cricket powder produced at various drying temperatures of 80, 90 and 100 ºC was shown in Fig. 6(a), (b) and (c), respectively. It was found that the cricket powder prepared using drying temperature of 100 ºC offered darkest brown color followed by the ones prepared using drying temperature of 90 ºC and 80 ºC, respectively.

Table 1. Average color value L*, a*, b* of dried cricket powder.

Drying temperature (ºC)	Average color of dried cricket powder		
	L*	a*	b*
80	44.15 ± 0.07^a	2.66 ± 0.06^a	5.43 ± 0.03^a
90	39.77 ± 0.84^b	2.04 ± 0.03^b	4.48 ± 0.06^b
100	37.50 ± 0.26^c	1.61 ± 0.04^c	3.77 ± 0.21^c

3.4 Moisture content and water activity

The moisture content was measured using moisture analyzer (moisture halogen mettle Toledo HX204) and water activity (aw) was analyzed using a water activity meter (AquaLab, 4TE). Table 2 showed that in order to reach the moisture content of approximately 5%, the required drying time decreased as drying temperature increased caused from an increase in vapor pressure of water within the cricket sample which resulted in faster mitigation of water to the surface. The aw value decreased as drying temperature increased. Noted that all samples were consistent with the dried food product specification (moisture content < 10%, water activity < 0.85) [21].

(a)

(b)

(c)

Fig. 6. Appearance of cricket powder produced at various drying temperatures (a) 80 °C (b) 90 °C and (c) 100 °C.

Table 2. Water activity of cricket powder with approximately 5% water content.

Drying Temperature (°C)	Drying time (min)	Moisture content (%)	Water activity
80	240±1.0[a]	5.32 ± 0.05	0.35 ± 0.02[a]
90	198±1.0[b]	5.25 ± 0.13	0.30 ± 0.02[b]
100	179±1.5[c]	5.29 ± 0.18	0.12 ± 0.01[c]

3.5 Solubility

The influence of tray drying temperature on the solubility of cricket powder with 5% moisture content was investigated at the same particle size of 120 mesh. Table 3 showed that increasing drying temperature caused an increase in solubility of cricket powders. Moreover, the effect of particle size on solubility was investigated by decreasing the particle size from 120 mesh (0.125 mm) to 140 mesh (0.105 mm). It was found that the solubility of cricket powder could be improved from 15.57 ± 0.29% to 17.43 ± 0.02 % as the particle size decreased.

Table 3. Solubility of cricket powder.

Drying temperature (°C)	Particle size (mesh)	Solubility (%)
80	120	10.26±0.13[c]
90	120	11.99±0.03[b]
100	120	15.57±0.29[a]

3.6 Proximate composition

The proximate analysis was conducted on cricket powder with a satisfying equilibrium moisture content, which had been produced by drying crickets at various temperatures. The outcomes of the analysis are presented in Table 4. The study revealed that drying the crickets at temperatures of 80°C, 90°C, and 100°C had minimal impact on the nutritional composition of the cricket powder. As the drying temperature increased, the levels of protein, fat, fiber, and carbohydrates in the cricket powder decreased. Optimal protein content was observed at a drying temperature of 80°C and a drying time of 240 minutes. Under these conditions, the proximate chemical composition (g/100 g) of the cricket powder on a dry basis was as follows: protein, 70.35 ± 0.23; fat, 18.38 ± 0.45; dietary fiber, 5.95 ± 0.15; ash, 4.83 ± 0.15; and carbohydrates, 6.53 ± 0.32. It is noteworthy that these findings align with previous studies indicating that protein and fat are the primary components of insect powder, as reported in the literature [22-23].

Table 4. Proximate analysis of cricket powder.

Component	Drying temperature (°C)		
	80	90	100
Protein	70.35±0.23[a]	69.80±1.11[ab]	68.98±0.12[b]
Fat	18.38±0.45[a]	14.02±0.20[b]	14.18±0.02[b]
Ash	4.83±0.15	4.81±0.30	4.66±0.24
Fiber	5.95±0.15[a]	5.21±0.30[b]	5.04±0.24[b]
Carbohydrate	6.53±0.32[a]	6.22±0.11[ab]	6.03±0.07[b]

4 Conclusion

The cricket powder was produced in this study using tray drying and grinding processes. The change in drying temperature (80, 90, 100°C) and drying time (ranging 0- 240 min) on the moisture content, drying rate of crickets and properties of cricket powder was investigated. The moisture content decreased as drying temperature increased whereas drying rate increased. The crickets could reach equilibrium moisture content approximately 5% fast at high temperature. The lightness of cricket powder decreased when drying temperature increased while the solubility indicated reverse trend. The solubility of cricket powder could be improved by decreasing the particle size. Regarding the nutrition, the change in drying temperature in a range of 80-100oC had no substantial effect on the protein content. The suitable drying condition of crickets offering the highest protein content of 70.35% was achieved at drying temperature of 80°C and drying time of 240 min. At this condition, 55.57% yield of cricket powder satisfying dry food specification (moisture content of 5.32% and aw of 0.3539) was achieved.

This work was supported by School of Food Industry, King Mongkut's institute of Technology Ladkrabang.

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