Quality of Instant Congee and Energy Consumption in the Drying Process by Using Drum Dryer

Weerachet Jittanit[1,2,*] Chalermchai Lalitmassakul[3] and Putchamol Charn-Utsar[3]

บทคัดย่อ

ในงานวิจัยนี้เป็นการทำแห้งโจ๊กไก่ปรุงสุกด้วยเครื่องทำแห้งแบบลูกกลิ้งคู่โดยใช้อุณหภูมิที่ 120 และ 140°ซ ความเร็วรอบของลูกกลิ้ง 0.5 รอบต่อนาที และระยะห่างระหว่างลูกกลิ้ง 0.2 มม. เพื่อที่จะผลิตโจ๊กกึ่งสำเร็จรูป โดยมีวัตถุประสงค์เพื่อศึกษาคุณภาพด้านกายภาพและด้านประสาทสัมผัสของโจ๊กกึ่งสำเร็จรูปที่ผลิตได้ และเพื่อประเมินต้นทุนพลังงานของกระบวนการทำแห้งโดยใช้ลูกกลิ้งคู่ จากผลการทดลองแสดงให้เห็นว่าค่าสีของผลิตภัณฑ์โจ๊กกึ่งสำเร็จรูปที่ถูกทำแห้งที่อุณหภูมิ 120 และ 140°ซ ไม่มีความแตกต่างกันอย่างมีนัยสำคัญ ในขณะที่ค่าความชื้นและค่าวอเตอร์แอกทีวิตี้ของผลิตภัณฑ์จากการทำแห้งที่อุณหภูมิ 140°ซ มีค่าต่ำกว่าผลิตภัณฑ์ที่ใช้อุณหภูมิ 120°ซ เล็กน้อย โจ๊กกึ่งสำเร็จรูปที่ผลิตที่อุณหภูมิ 140°ซ สามารถคืนรูปได้เร็วกว่าโจ๊กซึ่งผลิตที่อุณหภูมิ 120°ซ นอกจากนี้ตัวอย่างโจ๊กซึ่งถูกทำแห้งที่อุณหภูมิ 120 และ 140°ซ เมื่อผ่านการคืนรูปแล้วจะมีค่าความหนืดและคะแนนจากการประเมินคุณภาพทางประสาทสัมผัสในทุกๆ ด้านไม่แตกต่างกันอย่างมีนัยสำคัญ ต้นทุนพลังงานที่ใช้ในการทำแห้งมีค่าประมาณ 24.84 และ 35.82 บาท/กิโลกรัม$_{\text{ผลิตภัณฑ์}}$ สำหรับการทำแห้งที่อุณหภูมิ 120 และ 140°ซ ตามลำดับ

คำสำคัญ: การดูดน้ำกลับ การทำแห้ง เครื่องทำแห้งแบบลูกกลิ้ง โจ๊กกึ่งสำเร็จรูป พลังงาน

Abstract

In this research, the cooked chicken congee samples were dried by applying a double-drum dryer at the temperatures of 120 and 140°C, drum speed of 0.5 rpm, and the gap between drums of 0.2 mm to manufacture the instant congee product. The objectives were to determine the physical and sensorial qualities of instant congees from two drying conditions and to estimate the energy cost of drum drying process. The results indicated that the color of instant congee products dried at 120 and 140°C were not significantly different whereas the moisture content and water activity of products dried at 140°C were slightly lower than that of 120°C. The instant congee manufactured using the drying temperature of 140°C could rehydrate quicker than that of 120°C. Furthermore, the rehydrated congees from both samples had no significant difference in viscosity and their sensorial scores in all

1 Lecturer, Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University.
2 Researcher, Center for Advanced Studies for Agriculture and Food, KU Institute for Advanced Studies, Kasetsart University.
3 Student, Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University.
* Corresponding Author, Tel. 0-2562-5026, E-mail: fagiwcj@ku.ac.th

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aspects. The energy costs of drum drying processes were approximately 24.84 and 35.82 Baht/$kg_{product}$ for drying temperatures at 120 and 140°C respectively.

Keywords: Drying, Drum Dryer, Energy, Instant Congee, Rehydration

1. Introduction

Congee is a kind of food that is popular in many countries such as China, Philippines and Thailand. Liang et al. [1] claimed that congee is one of the three most common white-rice based foods for the Chinese population. It is mostly consumed either as a breakfast or a regular meal for the patient since it is not hard to be digested due to its soupy form. According to the survey of Liang et al. [1] at the hospitals in a province of southern China, the average congee consumptions of the interviewees were in the range between 242.7 and 352.3 g/week. However, a vital trouble faced by consumers is that the cooking of congee is a time-consuming and tedious process [2]. It is deemed inconvenient particularly for the modern lifestyle that requires short time for preparing food especially for breakfast. Therefore, the quick-cooking or instant congee is considered as a solution to eliminate the difficulties of cooking process of congee. Moreover, the instant congee is deemed as a food choice that has a definite ready market with the total sales of 22 million USD in Thailand alone [3].

To manufacture the instant congee, the drying process must be applied in order to extend the product shelf- life and create the porous structure for improving the rehydration ability of product. Srikaeo and Spade [3] stated that the processing of instant congee normally comprises with pre-cooking and then drying prior to mixing with other ingredients such as salt and sugar. Referring to Azanza et al. [2], their quick-cooking congee was manufactured using dehydrated rice, meat substitute in the form of textured vegetable protein, concentrated flavorings as dried spices and oleoresin forms, meat and chicken flavorings and hydrolysed vegetable proteins. The dehydrated rice in their work was prepared as the following procedures: hydration of the waxy rice in a mixture between calcium chloride and sodium citrate solutions at 50°C for 15-30 min, gelatinization of hydrated rice with steam pressure at 121.5°C for 2-5 min, convective air drying at 50-55°C until reaching moisture content of 8-10 % and finally puffing the dried rice by deep frying in vegetable oil at 200°C for 2 s. Although this manufacturing step can provide the product that is accepted by the consumers in the comparable level to the conventionally cooked congee and can rehydrate in boiling water within 5 min, the production procedure is somewhat complicate. One of an interesting drying technique that can be proficiently applied for the production of instant congee is drum drying.

Drum drying is usually used to dry a thin film of viscous, concentrated solutions, slurries or pastes on a rotating heated drum [4]. During the rotation of the drum, the film of dry solids on the drum surface is continuously removed by applying the doctor blade. Drum drying is a method extensively applied in food industry to manufacture food powder particularly for the heat-sensitive products where the short-time high-temperature drying is needed [5]. According to Srikaeo and Spade [3], for the industrial production the instant congees are usually dried by drum dryer. Imre [4] pointed out that the exposure of the thin film to the high heat flux for a short time period can create a porous structure to the dried film as a result of the rapid formation of vapour bubbles within the film. This porous structure is the desired feature for instant food products because it helps accelerating the rehydration process. According to Nastaj [5] and Pua et al. [6]. The drum drying parameters which can affect on the attributes of drum-dried food such as particle size, bulk density, moisture content, and solubility comprise with drying temperature, feed rate, rotation speed, feed concentration, and surrounding air condition.

Due to the lack of published information about the instant congee production and their physical and sensory qualities, this study was performed with the following aims; (1) to determine the physical and sensory qualities of instant congees produced from two drying conditions and (2) to estimate the energy cost of drum drying process. These information would be useful for the food industry that desires to produce the instant congee or any similar products.

2. Materials and Methods

2.1 Raw Materials

The chicken congee was prepared by the following procedures: seasoning the chicken breast mince with sugar, salt, soy sauce at the proportions of 1, 1 and 5% by weight of chicken mince respectively; boiling the broken rice KDML 105 variety with the ratio between rice and potable water of 1:6 by weight until well-cooked; putting the prepared chicken mince into the boiling rice at the ratio between the weight of broken rice and chicken mince of 1:0.2; after the chicken mince was cooked, adding the chopped shallot into the chicken congee at the ratio between broken rice and chopped shallot of 1:0.007 by weight. The chicken congee was grounded in the blender for 1 min and then cooled down by exposing it to the ambient air for at least 1 h before drum drying.

2.2 Drying Experiment

The chicken congee prepared by the procedure described in the previous section was used as the feed material in the drum drying experiments. The weight of feed material was 1 kg for each drying batch. The samples were dried in a local-made double drum dryer (drum diameter 22 cm and length 46 cm) with a 0.5 HP motor using a drum speed of 0.5 rpm and a gap between the drums of 0.2 mm. The drying experiments were carried out at two drying temperature levels (120 and 140°C). During the drying experiments, the data of steam pressure at the inlet of the drum dryer and inside the drum, the weight and the temperature of steam condensate at the dryer were recorded for the calculation of heat energy consumption. At the end of drying, the instant congee samples were collected, weighed, and kept in the sealed container for the quality determination.

2.3 Quality Determination

The colors, moisture contents, water activities and rehydration ratios of the instant congees collected from two drying runs were determined. In addition, the rehydrated instant congees were measured and evaluated for their viscosities and sensory qualities. Figure 1 illustrates the throughout procedure from the raw material preparation until the rehydrated instant congees were subjected to the quality determination. All the physical quality measurements were conducted in three replications.

2.3.1 Color

The colors of instant congee specimens were measured by "Minolta" color meter model CM-3500d (manufactured by Konica Minolta Sensing, Inc. Osaka, Japan) and expressed as L*, a* and b* values in CIE system.

2.3.2 Moisture Content

The moisture contents of samples were determined

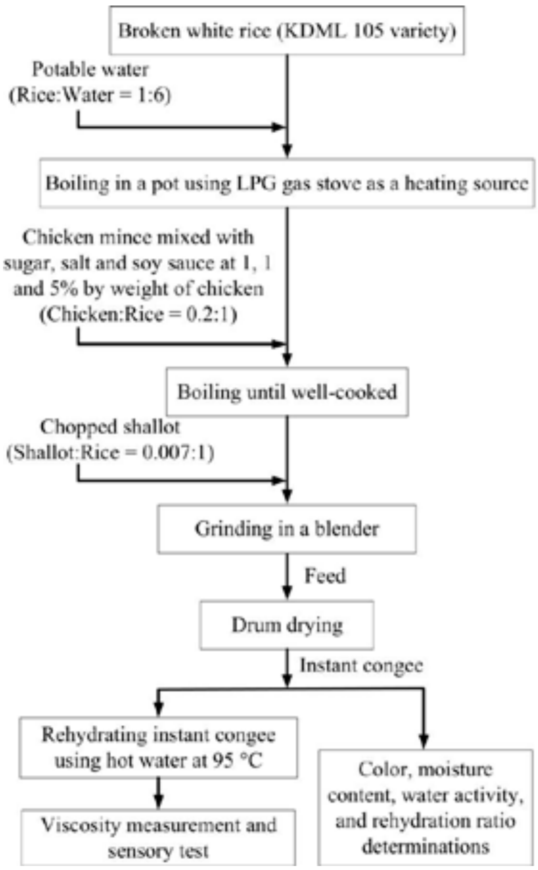

Figure 1 Procedure of the experiment.

by the oven method using 5 g of instant congee and 105°C drying temperature for 3 h. Afterward, the sample was cooled in a desiccator, weighed and re-dried for 1 h. The process was repeated until a change in weight between the successive dryings at 1 h intervals was less than 2 mg. The weight loss after drying in the oven was used to determine the moisture content of instant congee and was expressed on wet basis (WB). This moisture content determination was adapted from the method of Jittanit et al. [7].

2.3.3 Water Activity

The values of water activities of instant congee samples were measured by a "Novasina" water activity instrument, model TH2/RTD33 (made by Novasina AG, Lachen, Switzerland).

2.3.4 Rehydration Ratio

The method to determine the rehydration ratio of instant congee was adapted from that of Prasert and Suwannaporn [8]. The rehydration ratio was determined using 20 g of instant congee added with hot water at temperature of 95°C. After exposing the samples into hot water for specified time periods (2, 4 and 6 min), the excess water was drained for 5 min using the "Pyrex" 2 L suction flask with the buchner funnel diameter 185 mm and "WHATMAN" filter paper No 4. The suction flask was connected to the "ULVAC" vacuum pump model GLD-050 motor 200 W (manufactured by ULVAC Technologies, Inc., Methuen, MA 01844 USA). After draining the excess water, the samples were weighed. The rehydration ratio was calculated applying Equation 1.

$$\text{Rehydration ratio} = \frac{\text{Sample weight after rehydration}}{\text{Sample weight before rehydration}} \quad (1)$$

2.3.5 Viscosity

The viscosity of each rehydrated instant congee sample was measured using a "Brookfield" digital viscometer with the spindle no 27 (produced by Brookfield Engineering Laboratories, Inc., Middleboro, MA 02346 USA). For the rehydration step, the proportion of instant congee/hot water for each batch of sample was calculated using Equation 2 in order to rehydrate the instant congee to be similar to the feed materials.

$$WDWR = \left(\frac{WFM - WDP}{WDP}\right) * WPR \quad (2)$$

Where WDP is the weight of instant congee produced from the drying batch (kg), WDWR is the weight of hot water for rehydration (kg), WFM is the weight of feed mixture for the drying batch (kg) and WPR is the weight of instant congee for rehydration (kg).

2.3.6 Sensory Evaluation

Apart from the determinations of some physical qualities of instant congees as previously described, the rehydrated instant congee samples were subjected to the sensory test in aspects of color, taste, aroma, appearance and overall liking. The sensory qualities were evaluated using a 5-point hedonic scale test (5 = like extremely to 1 = dislike extremely) by 16 panelists who were randomly recruited from the students and staffs in the department. The number of panelists in this study is comparable to that of Jittanit et al. [9]

2.4 Energy Consumption for Drying Process

The energy consumption and energy costs of drum drying process for instant congee production were calculated. This information can be utilized as a guideline for the industry or researcher when they intend to do some economic evaluations.

The energy costs of drum drying were separated into two parts including heat energy and electrical energy. It is noted hereby that the energy cost calculated in this work excluded the energy consumed for warming up the drying system. The heat energy was calculated from the data of (1) steam pressure at the inlet of drum dryer, (2) steam pressure inside the drum, (3) the weight of steam condensate at the dryer and (4) the temperature of steam condensate. The data of steam pressure at the inlet of the dryer and that inside the drum were converted to be the temperatures of steam using the saturated steam table [10]. After that the heat energy was calculated from Equation 3. In this study, the steam boiler used the heat from the combustion of bio-diesel (B5) oil fuel that provides the approximate net heating values of 38,730 kJ/kg with a density of 0.875 kg/L to produce steam [11], [12]; hence, the fuel consumption for heat energy was calculated by Equation 4. Accordingly, the heat energy cost was calculated using Equation 5 when the B5 oil fuel price was 30 Thai Baht/L (31 Thai Baht ≈ 1 USD).

$$E_{heat} = m_c h_{fg} + m_c c_{p,g}(T_i - T_d) + m_c c_{p,f}(T_d - T_c) \quad (3)$$

$$FC = \frac{E_{heat}}{38{,}730 * 0.875} \quad (4)$$

$$HEC = 30 * FC \quad (5)$$

Where:

$c_{p,f}$ = specific heat of steam condensate (kJ/kg·°C)
$c_{p,g}$ = specific heat of saturated steam (kJ/kg·°C)
E_{heat} = heat energy (kJ)
FC = fuel consumption (L)
HEC = heat energy cost (Thai Baht)
h_{fg} = heat released by the steam inside the drum before condensation (kJ/kg)
m_c = mass of steam condensate during drying process (kg)
T_i = temperature of steam supplied by the boiler at the inlet of drum dryer (°C)
T_d = temperature of steam inside the drum (°C)
T_c = temperature of steam condensate (°C)

During the drying process, the electrical energy was consumed primarily by the driving motor of the double drums. Therefore, the electrical energy cost was calculated using Equation 6. The unit price of electricity was approximately 3 Thai Baht/kW·h (3 Thai Baht per 3.6 MJ of electrical energy).

$$EEC = P * t * UPE \quad (6)$$

Where:

EEC = electrical energy cost (Thai Baht)

P = motor power of drum dryer (kW)
t = operating time (h)
UPE = unit price of electricity (Thai Baht)

2.5 Statistical Analysis

The software package of SPSS version 12.0 was used for the analysis of variance (ANOVA) and a Duncan's multiple range test in the statistical analysis.

3. Results and Discussion

3.1 Quality of Instant Congee

Product color is one of the attributes that directly affects on the consumer sensation to the product. If considering the measured color values of instant congees including L* (lightness), a*(-, greenness) and b*(+, yellowness), it is clear that there was no significant difference between instant congees dried at 120 and 140°C. The explanation is that the drying times for these 2 drying conditions were identical and short because the rotation speed of the drum was set to be equal at 0.5 rpm; subsequently, the color change of product due to the chemical reactions such as Maillard reaction occurred at the comparable level although the drying temperatures were raised for 20°C. Additionally, the yellow color of instant products may be attributed proportionally to the soy sauce used for flavoring the chicken mince. However, when comparing the color of instant congee in this study to that of the dried cooked rice in the study of Luangmalawat et al. [13], the color of instant congee is slightly brighter but less yellow than that of dried cooked rice. This should be due to the differences in the raw materials and drying technique applied in the studies. It was noticed from the naked eyes that the color of instant congee produced in this study was similar to those commercially sold in the market.

The results in Table 1 also indicate that the instant congee samples in this study had moisture contents in the range between 1.5 and 1.8%wb. The moisture content of sample dried at 140°C was slightly lower than that of 120°C. It is because the heat and moisture transfer rates are usually enhanced if the drying temperature was boosted [5], [14]. The water activities of instant congees were directly related to their moisture contents. They ranged between 0.22 and 0.24 which are adequately low for long-term storage.

Table 1 Color, moisture content and water activity of the instant congee samples

Drying temp. (°C)	Color			M.C. (%wb)	a_w
	$L^{*,ns}$	$a^{*,ns}$	$b^{*,ns}$		
120	86.89 ± 3.69	– 0.87 ± 0.50	8.07 ± 1.14	1.8a ± 0.035	0.24a ± 0.005
140	90.43 ± 0.43	– 0.72 ± 0.14	8.26 ± 0.19	1.5b ± 0.015	0.22b ± 0.006

Note: ns = not significant different, L* = lightness ($0 \leq L \leq 100$), a*(+) = redness, a*(-) = greenness, b*(+) = yellowness and b*(-) = blueness; L*, a*, b*, M.C. (moisture content) and a_w (water activity) values are mean ± standard deviation (n = 3). Means with the different superscript within same column are significant different ($P < 0.05$).

According to the result in Figure 2, it was found that the rehydration ratios of samples from two drying runs were significantly different. That is the instant congee dried at 140°C could rehydrate more rapidly than that of 120°C. The reason is that the higher drying temperature leaded to the elevated heat flux resulting in the quick formation of vapor bubbles within the feed material during drum drying. These bubbles caused a porous structure inside the product and subsequently increased its contact surface area which helps accelerating the rehydration process [4]. Moreover, it appeared that during the first two minutes, the rehydration ratio speedily increased from 1 to 9.0 ±

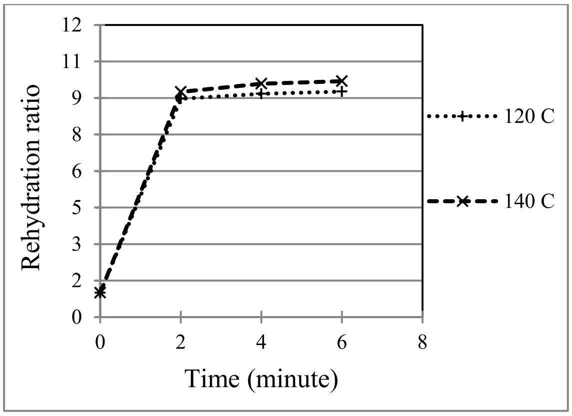

Figure 2 Rehydration ratios of instant congee samples from two drying runs after contacting hot water for 2, 4 and 6 min.

0.046 and 9.2 ± 0.049 for instant congee dried at 120 and 140°C respectively but the increase rate of rehydration ratio was enormously diminished along the subsequent time. The decrease of the moisture gradient between the surface and inner of product along the succeeding time is the explanation for the drop of the rehydration rate. The trend of the rehydration results in this study is analogous to that of dried cooked rice in the study of Luangmalawat et al. [13].

3.2 Quality of Rehydrated Instant Congee

The rehydrated instant congee samples were determined for their viscosity and sensory qualities as the result shown in Table 2. The results illustrated that there were no significant difference between the viscosity and the sensory test results of the samples dried at 120°C and those of 140°C. The explanation is that the drying times for these 2 drying conditions were identical and short while the difference in the drying temperatures were not large enough to cause the significant divergence in these quality attributes. Moreover, the sensory scores indicated that the panelists slightly like the instant congee. This sensory test results agree with the finding of Azanza et al. [2] who showed that the consumers slightly like both conventionally cooked meat congees and rehydrated congees from the instant products manufactured in their study.

Table 2 Viscosity and sensory test results of the rehydrated instant congees

Quality attribute		Drying temp. (°C)	
		120	140
Sensory test result (5 = maximum)	Color^{ns}	3.50 ± 0.52	3.56 ± 0.96
	Taste^{ns}	3.38 ± 0.50	3.56 ± 0.81
	Aroma^{ns}	3.94 ± 0.68	4.00 ± 0.96
	Appearance^{ns}	3.63 ± 0.50	3.69 ± 0.60
	Overall liking^{ns}	3.61 ± 0.22	3.70 ± 0.38
Viscosity^{ns} (cP)		264.67 ± 16.07	285.00. ± 32.69

Note: Sensory test score and viscosity are mean ± standard deviation (n = 16 for sensory test score and n = 3 for viscosity). ns = not significant different.

3.3 Energy Consumption

The energy consumption and energy costs for the drum drying process were calculated and summarized in Table 3. It appeared that the heat energy cost was the major energy cost of drying congee. The specific energy costs of drying process for producing instant chicken congee ranged between 24.84 and 35.82 Baht/kg$_{product.}$ The specific energy cost of drying at temperature of 140°C was remarkably higher than its counterpart because of its higher heat energy consumption. On the other hand, its electrical energy cost was lower than that of drying at temperature of 120°C since the operating time of the drum dryer at drying temperature of 140°C was shorter than that of 120°C. The energy costs for the drum drying process were deemed not expensive if comparing them with the market price of the instant congee sold in the

Table 3 Description of energy consumption and cost for the drum drying process

Drying temp. (°C)	Energy consumption for drying			Dried product weight (kg)	SPEC ($kJ/kg_{product}$)	Energy cost for drying		
	Heat energy (kJ)	Electrical energy (kJ)	Total primary energy (kJ)			Heat energy cost (Thai Baht)	Electrical energy cost (Thai Baht)	Specific energy cost (Thai $Baht/kg_{product}$)
120	3,177	1,007	5,795	0.147	39,425	2.81	0.84	24.84
140	4,735	772	6,742	0.135	49,944	4.19	0.64	35.82

Note: Total primary energy = Heat energy + [2.6*Electrical energy]. SPEC = specific primary energy consumption = Total primary energy/Dried product weight. Specific energy cost = (Heat energy cost + Electrical energy cost)/Dried product weight

marketplace (≈ 16 Baht/35 $g_{product}$).

The results in this study indicate that the production of instant congee using drum drying at 120°C can save the energy cost when comparing with drying at 140°C whereas the qualities of products from two drying conditions were comparable

4. Conclusion

The finding in this study demonstrated that the color of instant congee products dried at 120 and 140°C were insignificantly different. Nevertheless, the moisture content and water activity of instant congee dried at 140°C were slightly lower than that of 120°C. The water activities of instant congees produced in this study are low enough for long-term storage purpose. Furthermore, the instant congees can rehydrate rapidly and achieve the rehydration ratio of 9.0 within 2 min. The instant congee dried at 140°C could rehydrate slightly quicker than that of 120°C. There were insignificant difference between the viscosity and the sensory test scores of the sample dried at 120°C and those of 140°C. The sensory scores indicated that the panelists fairly like the instant congee. The specific energy costs of drying process for producing instant chicken congee ranged between 24.84 and 35.82 Baht/$kg_{product}$. The energy costs for the drum drying process were inexpensive if comparing them with the market price of the instant congee sold in the marketplace.

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