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Effect of Drying Temperature and Oil content on the Quality of Spray Dried Rice Bran Oil Powder Production

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Abstract

This research aims to investigate the effect of drying air temperature and oil-in-water emulsion composition on the quality of rice bran oil spray dried powder. Three-level full factorial design was applied to this research. Maltodextrin (DE 10) was used as encapsulated material. The oil phase with the concentration of 40% w/w which varied the weight ratio of oil content to maltodextrin of 1:2, 1:3 and 1:4 and drying air temperature with the inlet/outlet temperature of 170°C/70°C, 200°C/80°C and 230°C/90°C were examined. All spray drying conditions were performed in triplicate. Moisture content, water activity and product yield were analyzed. In addition, the peroxide value method was used to evaluate the extent of oxidation in products. Analysis of variance revealed that both drying temperatures and the weight ratio of oil content to maltodextrin influenced on production yield and moisture content. Besides, the oxidative quality of products was affected significantly by the oil content. Most of spray drying conditions was produced the rice bran oil powders with the moisture contents below 5% (w.b.) and some conditions were suitable for the spray dried rice bran oil production as production yields were above 60%. Overall, the optimal quality rice bran oil powder production in terms of production yield, moisture content and oxidative quality can be produced by spray drying at the weight ration of oil content to maltodextrin of 1:4 and drying temperature of 170/70°C.

Keywords: Rice Bran Oil, Spray Drying, Encapsulation.

1. Introduction

Rice bran oil is the oil extracted from the hard outer brown layer of rice after chaff. This byproduct corresponds from 8-11% (w/w) of the grain. It is notable for its high smoke point of 232°C. The rice bran oil has a high content of bioactive phytochemoicals and monounsaturated fatty acids. Rice bran oil contains γ-oryzanol, a natural antioxidant. Also significant is the relatively high fractions of tocopherols (vitamin E). Unsaturated fatty acids are nutritionally important for good health and the use of these fatty acids in health food formulations was increased in the last years (Roccia et al, 2014, Pohndorf et al, 2016).

Spray drying is one of the most widely used methods for the dehydration of foods. Spray dried powder has the benefit of good reconstitution, low water activity and moisture content that good for transport and storage (Master, 1991). However, stickiness on the drying chamber wall is one of the problem occurred in spray drying step. Feed solution can be successfully dried with improvement of spray drying condition. Water activity has been considered as one of the most important factors governing microbial growth. Water activity is related with moisture content. Product with the values of water activity under 0.6 is generally considered as microbiology safe and the values at 0.20 and 0.4 are stable against non-enzymatic browning, lipid oxidation and enzyme activity (Sigh and Anderson, 2000). This research aims to investigate the effect of drying air temperature and oil-in-water emulsion composition on the quality of rice bran oil spray dried powder. Full factorial design was set to find the optimal spray drying conditions for high quality powders and production yields.

2. Materials and Methods

2.1 Materials.

In this study, rice bran oil (cooking oil brand King, local market, Thailand) was used as encapsulated material. The encapsulating material was an aqueous solution of maltodextrin (MD) with DE 10, purchased from Thail food and chemical Co.Ltd, Thailand. Analytical grade petroleum ether was purchased from EMD Millipore Corporation (USA). All general chemicals used in this study were of analytical grade.

2.2 Feed preparation.

The emulsion comprised rice bran oil, maltodextrins (MD) and water. The total dry matter content of all initial emulsions (hydrophilic and lipophilic compounds) was 40% w/w in which the lipophilic compounds represented 8-13.3% w/w. Oil phase with the concentration of 40% w/w which varied the weight ration of oil content to maltodextrin of 1:2, 1:3 and 1:4.

2.3 Emulsions preparation.

Aqueous solutions were prepared by slow dissolution of the carrier(s) in water under mechanical stirring. Emulsions were obtained using a rotor–stator homogenizer (AXR, Silverson Machines Ltd, Fr) to disperse the oil phase into the aqueous one. Emulsions were homogenized for 20 min with a rotation speed of 3500 rpm.

2.4 Spray drying and experimental design.

Feed material was sprayed dried using a co-current spray dryer (JCM Minilab SDE-10, Thailand). The dimensions of the dryer are 1.2 m high, 0.97 m wide and 0.97 m long. A two fluid nozzle was used as an atomizer. The atomizer air pressure was set at 0.2 MPa and the liquid feed was supplied via a peristaltic pump. Inlet drying air temperature were set as 170, 200 and 230°C with varied outlet air temperature of 70, 80 and 90°C, respectively, using electrical heater. Volumetric drying air flow rate was constant at 32.13 m^3/h. Conditions were first established at a steady state using a feed of water before switching to the feed solution.

Experiments were planned applying a Three-level full factorial design. The oil phase with the concentration of 40% w/w which varied the weight ratio of oil content to maltodextrin of 1:2, 1:3 and 1:4 and drying air temperature with the inlet/outlet temperature of 170°C/70°C, 200°C/80°C and 230°C/90°C were examined.

2.5 Powder analysis.

2.5.1 Production yield.

The production yield was expressed as a percentage of the mass of rice bran oil powder obtained at the end of the spray drying experiment compared to the total amount of initial feed solution, including oil and maltodextrin, based on dry matter content.

2.5.2 Moisture content and water activity (a_w).

The moisture content of rice bran oil powder was determined by the AOAC Method 979.12 (1995) vacuum oven method, drying for 16 hours at 70°C and approximately 0.4 bar.

Water activity of the rice bran oil was determined using an AquaLab 3TE Series water activity meter (Decagon, USA). The temperature was maintained at 25.0±0.1°C during the tests.

2.5.3 Oil content measurement and total oil content coverage.

The oil content of rice bran oil powder was determined by the AOAC Method 945.16 (1995) Soxhet extraction. A powder sample of 3-5 g contained in a filter paper was measured and placed into the timble. Add 150 mL of petroleum ether into the flask, continue the extraction for 2 hours. The solution containing the extracted oil was dry for 1 hr at 105°C to evaporate the solvent.

Total oil content coverage was calculated by means of the percentage of the extracted oil content to the initial oil in emulsion feed.

2.5.4 Peroxide value (PV).

Generally, the peroxide value of and oil product is used to evaluate the oxidative rancidity of oil, by measuring the quantity of hydroperoxides in the oil. The PV method in this study was used by means of the methods used by Roccia et al. (2014) with some modifications. A powder sample of 5.0 g was dissolved in 12 mL chloroform. Immediately, 18 mL glacial acetic acid was added, and the mixture was stirred for a few seconds and added 0.5 mL saturated potassium iodide solution. Then 30 mL distilled water were added and the mixture was titrated with 0.1 N $Na_2S_2O_3$ using starch solution (1%) as an indicator.

2.5.5 Particle morphology.

Particle morphology was evaluated by scanning electron microscopy (SEM) ZEISS model EVO MA 10 at Instrument center of Advanced Manufacturing Innovation College, KMITL.

2.5.6 Statistical analysis.

The drying experiments and all analytical measurements were carried out in triplicate. Results were presented as mean values with standard deviations. Different mean values were analyzed by analysis of variance (ANOVA) and Tukey's pairwise comparison using Minitab software version 16.

3. Results and Discussion

Spray drying experiments were performd by using the various rice bran oil to maltodextrin content ration (1:2, 1:3 and 1:4) at the constant feed concentrations of 40% w/w and a range of inlet/outlet drying air temperature (170/70, 200/80 and 230/90°C). This experiments were used a constant feed concentration for controlling the amount of water evaporation. Statistical analysis results are presents in Table 1.

3.1 Production yield.

The production yield is one of the major factors describing the spray dried powder, it is expected to ontain higher yield. The production yield in this study varied from 45.08-73.56% (Fig. 1) and was significantly affected by the drying temperature and the oil content (Table 1). Higher production yield was obtained with increasing drying temperatures and the content of maltodextrin, as shown in Fig.1. The water evaporation at higher drying temperature occurs easier due to the greater efficiency of heat transfer, which decreasing the probability of particle adhesion on the spray dryer walls (Kha et al. 2014, Roccia et al. 2014). As the content of maltodextrin increased the yield was increasd. This was caused by the improvement of maltodextrin in the stickiness problem (Jafari et al. 2008). In comparison with the yield from a small-scale spray dryer, which should be more than 60% to be acceptable (Shofinita and Langrish, 2014). In this study, some conditions with the higher drying temperatures and maltodextrin contents show an acceptable spray dried rice bran oil production (Fig.1).

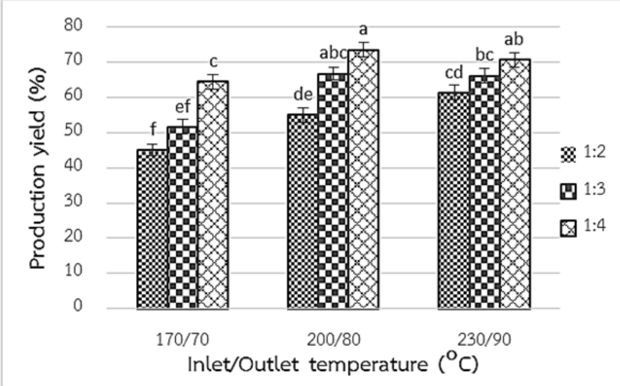


Figure 1 Production yields from spray drying experiments.

3.2 Moisture content and wate activity (a_w).

The moisture content of spray dried rice bran oil powder was in the range of 1.33-3.84% (wb) as shown in Table 2 and was significantly affected by the drying temperature and the oil content (Table 1). As can be seen in Fig.2, an increase in the drying temperatures and the maltodextrin contents resulted in a decrease in the moisture content. At higher drying temperature, a greater termperature difference between the wet particles and the drying air led to a higher rate of heat transfer, providing a greater driving force of evaporation. As a result, lower moisture content of the dried powders was obtained. The similar observation was also reported by several authors (Kha et al. 2014, Roccia et al. 2014). The moisture content of powders in this study was considered as a dry product. The moisture content of powders were lower than 5% which commomly observed in industrial spray drying (Vidović et al, 2014). Water activity is considered as one of the most importance quality aspects for the shelf life of powder. The water activity of spray dried powder varied from 0.10-0.21 (Fig. 3) and was significantly affected only by the drying temperature (Table 1) and considered as microbiology safe (Singh and Anderson, 2000). As the values at 0.20 and 0.4 are considered a stable range against lipid oxidation, only the conditions of inlet/outlet drying temperature of 170/70°C produced the qualified powders in lipid oxidation aspect.

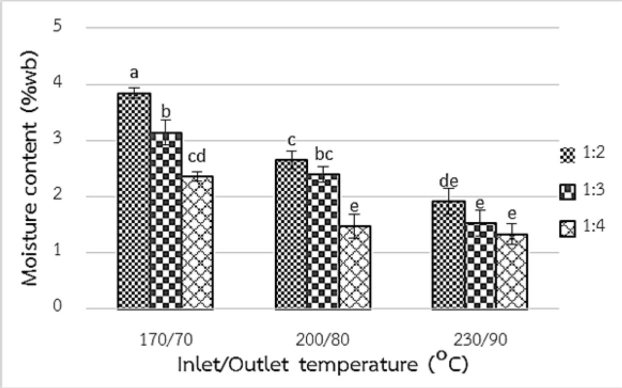


Figure 2 Moisture content of powders from spray drying experiments.

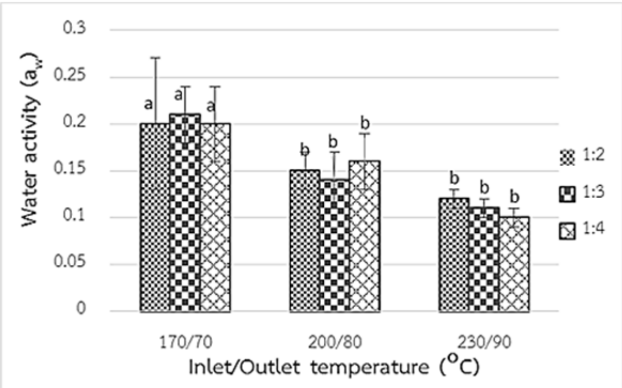


Figure 3 Water activity of powders from spray drying experiments.

3.3 Total oil content coverage.

In this study, the total oil content coverage varied from 32.94-47.48% and was not significantly affected both by the drying temperature and the oil content (Fig.4, Table 1). One of the explainations of the factors affecting the encapsulation efficiency is the droplet size of produced emulsion. Smaller the emulsion size, enhanced the encapsulation efficiency. According to Jafari et al. (2008), it is important to select the emulsification method to achieve maximum encapsulation efficiency. Microfluidization was the best emulsification method to produce the smaller emulsion size, Ultrasound method was the next order and Silverson rotor-stator emulsification was the poorest method for preparation of infeed solutions. In this study was used the Silverson rotor-stator emulsification for emulsion preparation that could caused the percentage of total oil coverage below 50% in this study.

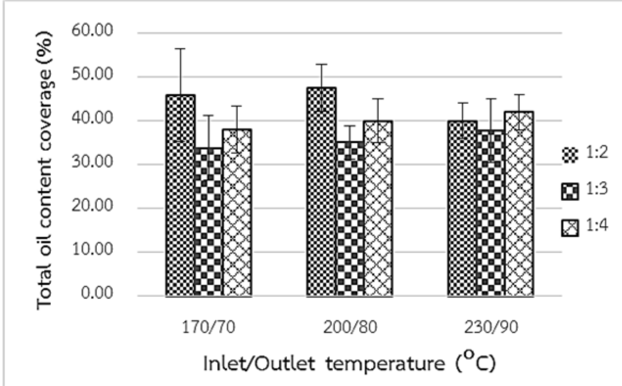


Figure 4 Total oil content coverage from spray drying experiment.

3.4 Peroxide value (PV).

The PV method was used to evaluate the rancidity of spray dried rice bran oil powder. In this study, the PV of the rice bran oil powder varied from 2.00 - 2.45 meq O_2kg^{-1}oil (Fig.5). The PV significantly increased with the decreasing oil content. However, the PV was not adversely affected by the drying temperature significantly. In this study, The PV results show a good potential of oxidative stable during the spray drying process. The PV of all spray dried rice bran oil powders were below the regulation of PV in oil (Notification of Ministry of Public Health No.205, B.E.2543, 2000), which allow up to 10 meq O_2kg^{-1}oil.

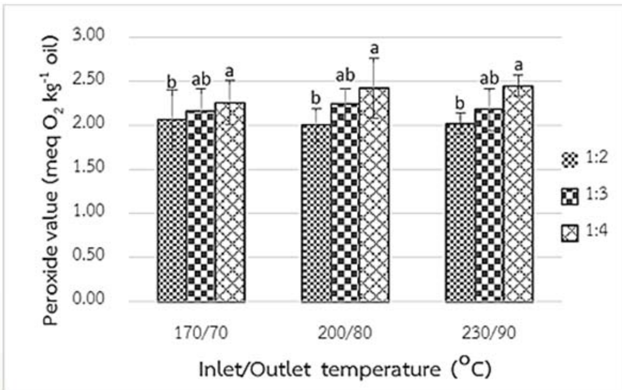
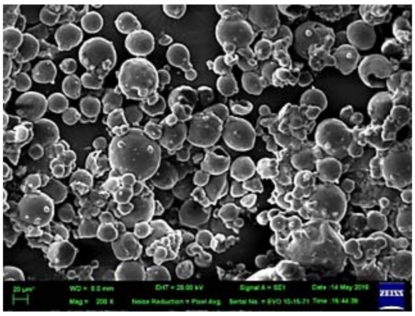


Figure 5 Peroxide value of powder from spray drying experiments.

3.5 Powder morphology.

The morphology of some spray dried rice bran oil powder was observed to understand the encapsulated particles. As can be seen in Fig.6 the spray dried rice bran oil powder were made of various sizes, hollow spherical shape particles with smooth surfaces and some indentation, which are the typical characteristics of microcapsules produced by spray drying (Kha et al, 2014). Most of particles show no apperent cracks or fractures, ensuring the retained oil in the powder particles.



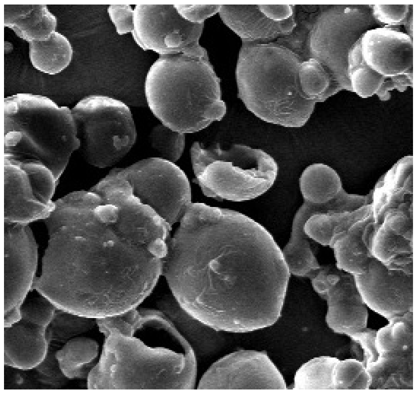


Figure 6 SEM of spray dried rice bran oil obtained from the drying temperature of 230°C and the ration of oil content to MD of 1:2 (A) and zoom section (B).

Table 1 the P-values obtained with ANOVA realized on the different factors affecting rice oil bran powder.

Response/factor	Production yield (%)	Moisture content (%wb)	Water activity	Total oil content coverage (%)	Peroxide value (meq O_2 kg^{-1} oil)
A : Drying Temperature	0.000 VS	0.000 VS	0.000 VS	0.529	0.817
B : Oil to MD ratio	0.000 VS	0.000 VS	0.953	0.057	0.011 S
A*B (interaction)	0.001 VS	0.003 VS	0.883	0.451	0.866

Significant levels: VS = very significant (p<0.01); S = significant (p<0.05)

4. Conclusions

The effect of drying temperatures and oil content on rice bran oil powder characteristics, in terms of production yield, moisture content, water activity, peroxide value and total oil content coverage were investigated. Drying temperatures and oil contents were affected significantly on production yield and moisture content of powders. With the optimal quality rice bran oil powder production in terms of production yield (more than 60%), moisture content (below 5%wb) and oxidative quality (a_w in the range of 0.2-0.4), the drying temperature of 170/70°C and the oil content with weight ration to maltodextrin of 1:4 was recommended for producing the greater quality of powder product.

5. References

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