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The Effect of Foam-mat Drying Parameters on the Quality of Instant Porridge Fortified with Kale as a Calcium source

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Abstract

The objective of this research was to develop instant porridge fortified with calcium for the elderly. This study aimed to investigate the effects of foaming and drying processes on the quality parameters of Leuang Pratew brown rice instant porridge. The results showed that using a 20% concentration of foaming agent and a whipping time of 10 minutes was suitable for producing the instant porridge. The foam porridge exhibited low density, high stability, and significant overrun. The optimized process for foam-mat drying involved a drying temperature of 65ºC and a drying time of 2 hours. The properties of the instant porridge were as follows: yield of 32.43%, moisture content of 4.03%, water activity of 0.356, water absorption index of 3.47 g/g, water solubility index of 36.89%, and glycemic index of 62.48. The sensory test using the 9-point hedonic scale indicated that the overall acceptance scores of the developed product were 7.46 (liked moderately). Nutrient analysis of the calcium-fortified instant porridge revealed a total energy of 365.26 kcal, total fat of 3.38 g, total protein of 22.36 g, total carbohydrate of 61.35 g, ash content of 9.81 g, moisture content of 3.30 g, calcium content of 3,604 mg/kg, and sodium content of 704 mg/kg. The microbiological qualities were within safe levels.

Keywords: *Calcium, Egg albumin, Foam-mat drying, Glycemic index, Leuang Pratew brown rice, Kale.*

1. Introduction

Virtually every country is experiencing an increase in the number and proportion of older people in their population. Old age is associated with degenerative conditions. The aging process affects the physiological system and problems with chewing and swallowing can lead to compromised eating. Thus, the elderly require specific types of food (Joshi, & Jadeja, 2017). Suitable nutrition is a key factor contributing to the good health of the elderly. Rice porridge is a popular dish in many Asian countries, especially in: China, Korea, Taiwan, Japan, and Thailand. It is easy to consume and provides a great source of nutrition. Nowadays, instant porridge is mostly made from white rice, which has fewer nutrients and a high glycemic index than pigmented rice (Nitikornwarakul et al., 2022). Rice varieties with medium glycemic index could be a healthier choice compared to the high glycemic varieties (Lerdluksamee et al., 2024). Leuang Patew rice has an amylose content of 30.80±0.28 g/100g. It's classified as high amylose and medium glycemic index values. Kale is a green leafy vegetable that belongs to the cabbage family Brassicaceae, which includes cabbage, broccoli, cauliflower, and sprouted cabbage. Kale has been called the queen of greens and accepted as a superfood (Jantawan, 2022). Kale has a high phytochemical content enriched with prebiotics and dietary fiber. Moreover, kale contains significant amounts of vitamins A, C, and K and the nutritional minerals potassium, calcium, and magnesium (Reda et al., 2021; Jantawan, 2022). Foam mat drying is a rapid drying process at low temperatures, cheaper than other drying techniques but preserving high quality attributes and bioactive retention of the dried product (Mounir, 2018; Reis et al., 2021). This technique has advantages such as a lower drying temperature, foam that accelerates the evaporation of water, low cost, and ease of use, which makes it cheaper and easier when compared to other usual methods of drying (Febrianto et al., 2012). This present study aimed to develop instant porridge fortified with calcium for the elderly containing medium glycemic index rice and high calcium from vegetables. Instant porridge fortified with calcium is an ideal food for elderly consumers and health-conscious consumers.

2. Objectives

1) To evaluate the effect of foaming process on foam density, foam stability, and overrun of porridge.

2) To investigate the effect of the drying process on the quality parameters of instant porridges.

3) To formulate instant porridges fortified with calcium.

3. Materials and methods

3.1 Preparation of porridge

For the preparation of porridge, Leuang Pratew brown rice was purchased from Chumphon province, Thailand. Rice was ground using a blender (Sharp, Thailand) with level 2 for 1 minute. The ground rice was cooked with a rice-to-water ratio of 1:11 for 15 min at 100°C. The porridge was then cooled to room temperature before further analysis.

3.2 Analysis of the foaming process on the properties of porridge foam.

The investigation of the foaming process focused on the concentration of the foaming agent and the whipping time. This study used egg albumin powder (Thai Food and Chemical Co., Ltd.) as a foaming agent. Leuang Pratew brown rice porridge foam was prepared by whipping Leuang Pratew brown rice with different concentrations of egg albumin powder at 10, 15, and 20% and whipping times at 10, 15, and 20 minutes. The foam characteristics were determined based on foam density, foam stability, and overrun.

3.2.1 Foam density

Leuang Pratew brown rice porridge foam of 30 mL was placed carefully in a measuring cylinder (Abd Karim, & Wai, 1999). The foam density was determined using equation (1) and expressed in g/cm^3

$$\text{Foam density (g/cm}^3\text{)} = \frac{\text{mass (g)}}{\text{volume (cm}^3\text{)}} \quad (1)$$

3.2.2 Foam stability

The stability of the Leuang Pratew brown rice porridge foam was determined by estimating the drainage volume. The porridge foam at 10 mL was gently transferred into a 250 mL beaker and left undisturbed for 2 hours. The drainage volume was measured by gently tilting the beaker and pouring the liquid collected at the bottom of the beaker into a measuring flask (Qadri, & Srivastava, 2014). Percent foam stability was calculated using equation (2).

$$\text{Foam stability(\%)} = \frac{\text{foam volume after 2 h(mL)}}{\text{initial foam volume of the foam(mL)}} \text{x100} \quad (2)$$

3.2.3 Overrun

The overrun of Leuang Pratew brown rice porridge foam in each treatment was determined by weighing 100 mL of Leuang Pratew brown rice porridge, then transferring it carefully into a 250 mL measuring cylinder and weighing it (Saentaweesuk, 2012). The overrun was determined using equation (3) and expressed in percentage.

$$\text{Overrun (\%)} = \frac{\text{volume of foam-volume of mixture}}{\text{volume of mixture}} \text{ x 100} \quad (3)$$

3.3 Optimization of the drying process on the quality parameters of instant porridges.

100 g of Leuang Pratew brown rice porridge foam was spread on a stainless steel tray with a thickness of 1 cm (500 g of foam per drying cycle). The foamed rice porridge was dried by using a tray dryer (Unique Tools Co., Ltd., Thailand) at 55ºC, 65°C, and 75ºC until reaching a moisture content of less than 10% w.b. The dried product was ground, kept in polypropylene bags, and stored at room temperature until the corresponding analysis. Leuang Pratew brown rice powder was then evaluated for its powder properties.

3.3.1 Powder yield

The powder yield was defined as the ratio of the dried weight of the product to the weight of initial sample multiplied by 100, as equation (4):

$$\text{Powder yield (\%)} = \frac{\text{weight of dried powder}}{\text{weight of Leuang Pratew brown rice porridge}} \times 100 \quad (4)$$

3.3.2 Moisture content

The moisture content of porridge powder was determined according to a standardized AOAC gravimetric method as the difference in mass between the original sample and the sample dried for 3 hours at 105°C (AOAC, 2000).

3.3.3 Water activity

The water activity of the powder was determined using a water activity meter (Novasina, Switzerland) at 25°C.

3.3.4 Water absorption index and water solubility index

The water absorption index (WAI) was determined as described by Anderson et al. (1969). Instant porridges were suspended in water at room temperature for 30 minutes by gently stirring and then centrifuged at 3000g for 15 minutes. An aliquot of the supernatant was removed from the pre-weighed Petri dish and immediately oven-dried at 135°C for 8 hours. The supernatant was decanted and calculated for water solubility using equation (5) and reported in the unit of g/g.

$$\text{WAI (g/g)} = \frac{\text{weight of sediment}}{\text{dry weight of instant porridges}} \quad (5)$$

The water solubility index (WSI) was the weight of sediment to the dry weight of the sample multiplied by 100, as equation (6):

$$\text{WSI (\%)} = \frac{\text{weight of dissolved solid in supernatant}}{\text{dry weight of instant porridges}} \times 100 \quad (6)$$

3.3.5 Glycemic index

The glycemic index was investigated by the method reported in Goniet et al., (1997). The instant porridge was sent to the Research Institute for Health Sciences, Chiang Mai University, for an in vitro digestibility test of hydrolysis index and glycemic index.

3.4 Development formulation of instant porridges fortified with calcium.

3.4.1 Determination of calcium content

Kale, a source of calcium, was used in this research. Kale varieties such as curly kale, red Russian kale, lacinato kale, and purple curly kale were collected from the Barramepirun plant factory. Samples were sent to the central lab for calcium determination. The method used was an in-house method TE-CH-134 based on AOAC (2019) 98427 by ICP-OES technique.

3.4.2 Instant porridge preparation

Kale was used as a calcium source for porridge. Kale was blanched at 100°C for 1 minute and dried at 55°C for 2 hours (Araújo, 2015). Other ingredients were peeled, cut into 2.5 cm^3 pieces, and dried in a tray dryer at 65°C until the moisture content dropped to less than 12% w.b., as per the Thailand Industrial Standard for instant rice porridge (TIS 136-2558). The ingredients were then mixed and ground in a blender. The formulation of the calcium-fortified instant porridge consisted of 69.5% dried Leuang Pratew brown rice porridge; 15% chicken breast powder; 10% kale powder; 2.5% carrot powder; 2.5% pumpkin powder; and 0.5% seasoning powder.

3.4.3 Sensory properties

The ballots consisted of three questions to rate the intensity of kale color, egg albumin odor, and saltiness using a Just About Right (JAR) scale with five options: much too strong, somewhat too strong, just right, somewhat too weak, and much too weak. The JAR results served as guidelines for improving the formulation of the calcium-fortified instant porridge. At least 70% of responses should be at the just-about-right level to conclude that a specific attribute is at its optimal level. The binomial test was used for analysis if the data had a JAR percentage less than 70%.

3.4.4 Formulation of instant porridges

The formulation improvements based on the JAR results were to reduce the intensity of color with different concentrations of kale at 10, 7.5, and 5%. Sensory evaluation was conducted with 50 elderly panelists aged 60-70 years. The 9-point hedonic scale with scores ranging from 9 (like extremely) to 1 (dislike extremely) was employed. The evaluated parameters included five attributes: color, aroma, taste, texture, and overall acceptability.

3.5 Determination of powder property

3.5.1 Nutrients analysis

The nutritive values of instant porridges, including total fat, protein, ash, and moisture, were determined according to the AOAC method (2000). Carbohydrate was calculated by deducting one hundred percent of the sum of the percentages of total fat, protein, ash, and moisture. The energy was the result of the total amount of carbohydrates, protein, and fat multiplied by 4, 4, and 9, respectively. The product was sent to an Asian medical and agricultural laboratory and research center for the determination of calcium and sodium.

3.5.2 Product quality

Products were evaluated for microbiological quality compared to the requirements of the Thailand Industrial Standard for Instant Rice Porridge (TIS 315-2564).

3.6 Statistical Analysis

All measurements were done in triplicate. The data were analyzed using one way analysis of variance (ANOVA) method. Duncan's multiple range (DMR) test ($p \leq 0.05$) was used to compare means using the SPSS 18 software.

4. Results

4.1 Effect of the foaming process on the properties of porridge foam.

The foam concentration significantly effected foam density ($p \leq 0.05$). Foam density inversely increased with foaming agent. The foam's densities ranged from 0.55 to 0.67 g/cm^3 (Table 1.). Whipping time was directly correlated with the density of the foam. As the whipping time rose from 10 to 20 minutes, the density of the foam increased.

The foam stability was not significantly impacted by the amount of foam or the duration of whipping. All the concentrations of foam remained stable and showed no drainage even after 2 hours.

The overrun was significantly affected by foam concentration and whipping duration ($p \leq 0.05$). Foam overrun expanded with an increase in foam concentration. Overrun ranged from 8.12 to 13.23%, with foam concentration increasing from 10 to 20 % by weight. While overruns decreased with whipping time, a 20% foam concentration and 10 minutes of whipping were found to be optimal. The foam was stable, with the lowest density and the highest overrun.

4.2 Optimization of the drying process on quality parameters of instant porridges

Temperature significantly influenced ($p \leq 0.05$) the yield of the porridge. The yield of foam-mat dried powder decreased with increasing drying temperature from 55°C to 75°C, the yield ranged from 26.23% to 40.80%. At the same drying time, the highest product yield was observed when dried at 65°C for 2 hours, showing a significant difference ($p \leq 0.05$). The results indicated that foam-mat drying is an appropriate food processing method for powder production, as it can reduce the moisture to less than 10%. The drying temperature had a statistically significant ($p \leq 0.05$) effect on the moisture content. The moisture content ranged from 0.84% to 35.94%. Table 2 presents the effect of drying temperature on moisture content. The results showed the moisture content of instant porridge decreased with increasing drying temperature and drying time. At the same drying temperature, a higher drying temperature resulted in lower moisture content. According to the Thailand Industrial Standard of instant rice porridge (TIS 315-2564), a moisture content of less than 10% is required. Therefore, the product was dried for 3 hours at 55°C, 2 hours at 65°C, and 2 hours at 75°C.

The drying temperature significantly affected the water activity of instant products ($p \leq 0.05$). The findings presented in Table 3 reveal that as the drying temperature increased, the water activity of the powder also increased, with values of 0.277, 0.356, and 0.381, respectively. However, microorganisms do not grow at these levels of water activity.

Drying temperature also significantly influenced the water absorption index of the instant porridge ($p \leq 0.05$). The water absorption index of the instant porridge, as shown in Table 3, ranged from 3.32 g/g to 3.71 g/g. The highest water absorption index was observed at a drying temperature of 75°C, followed by 65°C, with 55°C having the lowest value. Similar results have been reported by Aksit, & Genccelep (2021), indicating that solubility increased with rising temperature. The water solubility index values varied from 36.34% to 39.65%, as shown in Table 3. The highest water solubility index was observed at 75°C, followed by 65°C, with the value at 55°C. Although the drying temperature enhanced the water solubility index, the differences were not significant amongst 55°C, 65°C, and 75°C. This finding is consistent with the results of Asokapandian et al. (2016). The present study also demonstrated that the glycemic index (GI) varied but was not significantly different ($p > 0.05$) between drying temperatures. The GI value of Leuang Pratew brown rice porridge increased from 61.54% to 63.80%, with the lowest GI observed at 55°C and the highest at 75°C.

Table 1 Foaming characteristics of Leuang Pratew brown rice porrdges

Foaming characteristics	Whipping time (minute)	Foaming agent (%)		
		10	15	20
Foam density (g/cm^3)	10	0.62±0.29^{bc}	0.66±0.02^{ab}	0.67±0.02^{a}
	15	0.62±0.02^{c}	0.64±0.03^{abc}	0.63±0.02^{bc}
	20	0.55±0.02^{d}	0.62±0.02^{bc}	0.62±0.03^{bc}
foam stability (%)	10^{ns}	100.00±0.00	100.00±0.00	100.00±0.00
	15^{ns}	100.00±0.00	100.00±0.00	100.00±0.00
	20^{ns}	100.00±0.00	100.00±0.00	100.00±0.00
Overrun (%)	10	9.21±0.04^{e}	8.18±0.08^{g}	8.12±0.20^{g}
	15	9.93±0.11^{c}	9.38±0.02^{de}	8.66±0.18^{f}
	20	13.23±0.12^{a}	10.54±0.11^{b}	9.52±0.06^{d}

^{ns} Means in same row are non-significantly different (p>0.05).

Table 2 Instant porridges yield and moisture content percentages at drying temperatures and times.

Instant porridges characteristics	Drying temperature (°C)	Drying time (minute)				
		1	2	3	4	5
Yield (%)	55	40.80±0.09^{a}	30.81±0.08^{e}	27.96±0.06^{h}	27.42±0.03^{i}	26.23±0.03^{j}
	65	37.84±0.12^{b}	32.43±0.19^{c}	32.01±0.02^{d}	30.82±0.11^{e}	29.86±0.05^{f}
	75	40.79±0.56^{a}	30.78±0.03^{e}	28.12±0.02^{g}	27.96±0.01^{h}	27.41±0.12^{i}
Moisture content (%)	55	35.94±0.23^{a}	13.16±0.69^{c}	4.75±0.37^{d}	3.23±0.56^{f}	3.08±0.09^{fg}
	65	15.28±0.56^{b}	4.03±0.13^{e}	2.83±0.04^{fgh}	2.51±0.11^{gh}	2.39±0.23^{h}
	75	15.34±0.88^{b}	1.69±0.09^{i}	1.63±0.22^{i}	1.22±0.08^{ij}	0.84±0.14^{j}

Table 3 The chemical characteristics of LeuangPratew brown rice instant porridges

Chemical characteristics	Drying temperature (°C)		
	55	65	75
A_w	0.277±0.04^{b}	0.356±0.03^{a}	0.356±0.03^{a}
WAI	3.32±0.07^{b}	3.47±0.09^{ab}	3.71±0.29^{a}
WSI^{ns}	36.34±2.38	36.89±0.65	39.65±6.77
GI^{ns}	61.54±0.63	62.84±1.17	63.80±0.72

$^{a-c}$ Means in same row with different letters are significantly different (p≤0.05).
^{ns} Means in same row are non-significantly different (p>0.05).

Table 4 Calcium content of kale

Varieties of kale	Calcium content(mg/kg)
curly kale	3,597.67^{a}
red Russian kale	1,673.10^{d}
lacinato kale	2,955.03^{c}
purple curly kale	3,147.33^{b}

$^{a-d}$ Means in same column with different letters are significantly different (p≤0.05).

Table 5. Result of JAR sensory attributes based on percentages

Sensory attribute	Much too strong	Somewhat too strong	Just right	Somewhat too weak	Much too weak	Net effect
Kale color	6	74	20	-	-	80
Egg albumin odor	8	22	70	-	-	-
salty	-	-	78	18	4	-

4.3 Development formulation of instant porridges fortified with calcium

The varieties of kale used for this study were curly kale, red Russian kale, lacinato kale, and purple curly kale as shown in Table 4. The calcium content of kale was 3,597.67 mg/kg, 1,673.10 mg/kg, 2,955.03 mg/kg, and 3,147.33 mg/kg, respectively. Table 4 shows that curly kale had the highest calcium content.

The formulation of the instant porridge from 3.2.2 was dried for 2 hours at 65°C, then used for sensory evaluation. The JAR results of Leuang Pratew brown rice instant porridge for three attributes were analyzed based on a normal JAR percentage of 70%. As shown in Table 5, the sensory attributes of egg albumin odor and saltiness had JAR percentages higher than 70%, indicating no need for improvement. However, the sensory attribute of kale color had a JAR percentage lower than 70%, indicating the need for further improvement. To address this, the kale content was decreased by two scales to reduce the intensity of the kale color.

A suitable formulation of instant porridges was evaluated on a hedonic 9-point scale. The consumer acceptance score is demonstrated in Table 6. The mean liking scores for formula 3 regarding color, odor, taste, texture, and overall acceptance ratings were significant ($p \leq 0.05$). The results demonstrated that the suitable formulation was formula 3, which had the lowest kale content and consisted of 69.5% dried Leuang Pratew brown rice instant porridge; 15% chicken breast powder; 5% kale powder; 2.5% carrot powder; 2.5% pumpkin powder; and 0.5% seasoning powder.

4.4 Determination of powder property

The results of the nutrient analysis of instant porridges are presented in Table 7. The product had the following nutritional values: fat 3.38 g, protein 22.36 g, total carbohydrate 61.35 g, ash 9.81 g, and moisture content 3.30 g. The total energy of the porridge was 356.26 kcal. The calcium and sodium content were 3,604 mg/kg and 704 mg/kg, respectively.

The Leuang Pratew brown rice instant porridge was calculated for the percentage of Thai RDI for calcium. The percentage of calcium in the product was 22%. Therefore, this product can be considered a source of calcium.

Table 8 showed the microbiological quality of instant porridge. The total microorganism 5.4×10^3 CFU/g, Mold 1.0×10 CFU/g, *Bacillus cereus* 1.0×10^2CFU/g. While, *Clostridium perfringens*, *Escherichia coli* and *Staphylococcus aureus* were less than 10 CFU/g, 3 MPN/g, and 10 CFU/g, respectively. Nevertheless, *Salmonella* spp. was not detected in instant porridge.

Table 6. Consumer acceptance score of three formulations of Leuang Pratew brown rice instant porridge

Attributes	Formula		
	1	2	3
color	6.30 ± 0.79^c	6.86 ± 0.70^b	7.60 ± 0.86^a
odor	6.44 ± 0.97^c	7.04 ± 0.81^b	7.44 ± 0.61^a
taste	6.40 ± 0.90^c	6.92 ± 0.75^b	7.36 ± 0.48^a
texture	6.80 ± 0.73^c	7.14 ± 0.61^b	7.40 ± 0.53^a
Overall acceptance	6.50 ± 0.93^c	6.92 ± 0.75^b	7.46 ± 0.50^a

$^{a-c}$ Means in same row with different letters are significantly different ($p \leq 0.05$).

Table 7. Nutrient analysis of Leuang Pratew brown rice instant porridge

Composition	Result
Fat	3.38 g
Protein	22.36 g
Total carbohydrate	61.35 g
Ash	9.81 g
Moisture content	3.30 g
Total energy	356.26 kcal
Calcium	3,604 mg/kg
Sodium	704 mg/kg

Table 8 Microbiological qualities of Leuang Pratew brown rice instant porridge compared to Thailand Industrial Standard of instant rice porridge (TIS 315-2564).

Microbiological Qualities	Thailand Industrial Standard (TIS 315-2564)	Leuang Pratew brown rice instant porridge
Total microorganism	1 x 10^5 CFU/g	5.4x10^3 CFU/g
Mold	< 1 x10^2 CFU/g	1.0x10 CFU/g
Bacillus cereus	< 2 x10^2 CFU/g	1.0x10^2 CFU/g
Clostridium perfringens	< 100 CFU/g	Less than 10 CFU/g
Escherichia coli	< 3 MPN/g	Less than 3 MPN/g
Staphylococcus aureus	< 100 CFU/g	Less than 10 CFU/g
Salmonella spp.	Not detected	Not detected

5. Discussion

The quality of foam influences thermal properties such as air incorporation and flow viability during dehydration (Sifat et al., 2021). Foam density, foam stability, and overrun are properties that affect the stability and efficiency of foams (Franco et al., 2016; Afifah et al., 2023). This study observed that as foam concentration increased, foam density decreased, and the overrun increased. A high concentration of egg albumen causes a decrease in the foam density due to the reduction in the interfacial tension and surface tension of the liquid, forming an interfacial film (Affandi et al., 2017). The lower foam density indicates more air being entrapped in the foam, and the foam expands, which aids in thermal conductivity (Sifat et al., 2021). Similar trends of decreasing density with increased foam concentration were shown in previous studies (Thuwapanichayanan et al., 2008; Kandasamy et al., 2012; Sangamithra et al., 2015; Franco et al., 2016; Affandi et al., 2017; and Kebngoen, 2019). During whipping, air is trapped in the liquid, forming more bubbles (Thuwapanichayanan et al., 2008; Sangamithra et al., 2015; Afifah et al., 2023, Munlum, & Junsi, 2024). As bubbles increase, foam density decreases while foam formation increases (Falade et al., 2003). A higher egg albumin content leads to expanded foam because higher protein content forms a sticky and elastic film, trapping air during whipping (Franco et al., 2016). However, higher protein levels cause lower foam density and greater foam stability (Chandrasekar et al., 2015). Foam overrun increases with foam concentration, as does foam density. At low foaming agent concentrations, foam is easily drained, leading to a low overrun value due to reduced surface and interfacial tension. Increasing foam concentration enhances the liquid phase viscosity, preventing air trapping during whipping (Inchuen, & Duangkhamchan, 2021). Thus, the overrun increases with foam concentration.

The average product yield varied from 26.23% to 40.80%. As expected, product yield decreases with the drying temperature increasing. Higher temperatures cause more water evaporation during the process, hence reducing product yield. Similar studies found that the moisture content of the product decreased with increased drying temperature. The changes in moisture loss during drying are shown in Table 3. Moisture content loss is rapid during the initial drying stage and then gradually reduces until minimum moisture content is achieved (Thuy et al., 2022). A similar trend was found by Niyomwet et al. (2018). The product had a moisture content of less than 10% w.b., conforming to Thailand Industrial Standard requirements. Microbial growth stability is a function of water activity. The water activity level that limits the growth of most pathogenic bacteria is 0.9 A_w, spoilage molds are 0.7 A_w, and the lower limit for all microorganisms is 0.6 A_w (Decagon Devices, 2006). The powder's water activity ranged from 0.277 to 0.381, as shown in Table 3, with values below 0.6 A_w, indicating that the product powder from this process is safe from microbial growth.

Drying conditions influence the solubility and water absorption index of food powders obtained by foam-mat drying (Franco et al., 2016). Higher drying temperatures provide higher values of adsorption and solubility index. WAI and WSI increased as the drying temperature increased (Dehghannya et al., 2019). However, WSI showed no significant difference when the temperature increased from 55°C to 75°C. Generally, when the drying temperature increased, the foam structure dried rapidly due to the increased material surface area by incorporating gas or air and forming porous structures. The more porous the foam structure, the greater the heat transfer and drying rate, resulting in an enhancement of WAI and WSI (Afifah et al., 2023).

The different processing methods used may influence the GI of a particular food (Bahado-Singhet et al., 2006). Drying may cause gelatinization and cell/starch granule rupture, releasing the constituents and making these more accessible to enzymatic digestion (Senadheera, & Ekanayake, 2013). GI increases as the degree of gelatinization increases in a product. The GI value is higher in preheated foods compared to less processed foods (Björck et al., 2000). The food processed within the skin using dry heat, cause a loss of water and concentrating free sugars within the food. The degradation of starches further increases the total sugar content, resulting in high GI values (Bahado-Singh et al., 2006). The particle size of a food is a key factor in controlling the glycemic response. A larger particle size distribution would have a lower GI value. The high surface area might increase the digestibility of foods with fine particles, thus increasing the GI (Senadheera, & Ekanayake, 2013).

The experiment indicated that the optimum drying process for Leuang Pratew brown rice porridge was at 65°C for 2 hours. The quality of instant porridges showed higher yield, and water absorption index ($p \leq 0.05$). This process resulted in a moisture content conforming to Thailand Industrial Standard for instant rice porridge (TIS 315-2564). Furthermore, the guidelines for microbiological quality of instant porridge (Thai Industrial Standards Institute Ministry of Industry, 2021) indicated satisfactory levels for total microorganisms ($\leq 10^5$ cfu/g), mold ($\leq 10^2$ cfu/g), and *Bacillus cereus* ($\leq 2x10^2$ cfu/g). Acceptable ranges for *Clostridium perfringens*, *Escherichia coli*, and *Staphylococcus aureus* are $\leq 10^2$ cfu/g, <3 MPN/g, and $\leq 10^2$ cfu/g, respectively. The absence of *Salmonella* spp. indicates low risk of foodborne diseases (Nethathe et al., 2023). The product showed microbiological quality within acceptable limits for instant porridge.

6. Conclusion

The appropriate foam mat drying process for Leuang Pratew brown rice porridge fortified with kale as a source of calcium involved a foaming agent of 20%, whipping time of 10 minutes, drying temperature of 65°C, and drying time of 2 hours. The calcium-fortified instant porridge consisted of 74.5% instant Leuang Pratew brown rice powder, 15% chicken breast powder, 5% kale powder, 2.5% carrot powder, 2.5% pumpkin powder, and 0.5% seasoning powder. The overall acceptance scores of the developed products were 7.46 (moderate like). The product was safe for consumption and met the requirements of Thailand Industrial Standard of instant rice porridge (TIS 315-2564).

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8. References

Abd Karim, A., & Wai, C. C. (1999). Foam-mat drying of starfruit (Averrhoa carambola L.) puree. Stability and air drying characteristics. *Food chemistry*, *64*(3), 337-343. https://doi.org/10.1016/S0308-8146(98)00119-8

Affandi, N., Zzaman, W., Yang, T. A., & Easa, A. M. (2017). Production of Nigella sativa beverage powder under foam mat drying using egg albumen as a foaming agent. *Beverages*, *3*(1), Article 9. https://doi.org/10.3390/beverages3010009

Afifah, N., Indrianti, N., Ratnawati, L., Putri, D. P., Yulianti, L. E., Rahmawati, L., ... & Sarifudin, A. (2023). The effect of sugar cane concentration on foam-mat drying kinetics and physicochemical properties of dried-tomato pasta sauce. *Emirates Journal of Food and Agriculture*, *35*(5), 442-451. https://doi.org/10.9755/ejfa.2023.v35.i5.3096

Aksit, Z., & Genccelep, H. (2021). Investigation of Tomato, Quince and Grapefruit Waste; Compositions and Functional Properties. *Hittite Journal of Science and Engineering*, *8*(1), 19–26. https://doi.org/10.17350/HJSE19030000208

Anderson, R. A., Conway, H. F., & Peplinski, A. J. (1970). Gelatinization of corn grits by roll cooking, extrusion cooking and steaming. *Starch-Stärke, 22*(4), 130-135. https://doi.org/10.1002/star.19700220408

AOAC. (2000). *Official Methods of Analysis of AOAC International*. AOAC International.

Araújo, A. C., Oliveira, S. M., Ramos, I. N., Brandão, T. R. S. & Silva, C. L. M. (2015). Effect of pretreatments on quality parameters & nutritional compounds of dried Galega kale (Brassica oleracea L. var.

acephala). UniversidadeCatolica Portuguesa. https://repositorio.ucp.pt/handle/10400.14/19850

Asokapandian, S., Venkatachalam, S., Swamy, G. J & Kuppusamy, K. (2016). Optimization of foaming properties and foam mat drying of muskmelon using soy protein. *Journal of Food Process Engineering, 39*, 692–701. https://doi.org/10.1111/jfpe.12261

Bahado-Singh, P. S., Wheatley, A. O., Ahmad, M. H., Morrison, E. S. A., & Asemota, H. N. (2006). Food processing methods influence the glycaemic indices of some commonly eaten West Indian carbohydrate-rich foods. *British journal of nutrition*, *96*(3), 476-481. https://doi.org/10.1079/BJN20061792

Björck, I., Liljeberg, H., & Östman, E. (2000). Low glycaemic-index foods. *British Journal of Nutrition*, *83*(S1), S149-S155. https://doi.org/10.1017/s0007114500001094

Chandrasekar, V., Gabriela, J. S., Kannan, K., & Sangamithra, A. (2015). Effect of foaming agent concentration and drying temperature on physiochemical and antimicrobial properties of foam mat dried powder. *Asian Journal of Dairy and Food Research*, *34*(1), 39-43. https://doi.org/10.5958/0976-0563.2015.00008.1

Decagon devices. (2006). Water activity news, Decagon. Retrieved from https://issuu.com/decaweb/docs/awnews04

Dehghannya, J., Pourahmad, M., Ghanbarzadeh, B., & Ghaffari, H. (2019). Heat and mass transfer enhancement during foam-mat drying process of lime juice: Impact of convective hot air temperature. *International Journal of Thermal Sciences*, *135*, 30-43. https://doi.org/10.1016/j.ijthermalsci.2018.07.023

Falade, K. O., Adeyanju, K. I., & Uzo-Peters, P. I. (2003). Foam-mat drying of cowpea (Vigna unguiculata) using glyceryl monostearate and egg albumin as foaming agents. *European Food Research and Technology*, *217*, 486–491. https://doi.org/10.1007/s00217-003-0775-3

Febrianto, A., Kumalaningsih, S., & Aswari, A. W. (2012). Process engineering of drying milk powder with foam mat drying method, a study of the effect of the concentration and types of filler. *Journal of Basic and Applied Scientific Research*, *2*(4), 3588-3592.

Franco, T. S., Perussello, C. A., Ellendersen, L. N., & Masson, M. L. (2016). Effects of foam mat drying on physicochemical and microstructural properties of yacon juice powder. *LWT - Food Science and Technology*, *66*, 503-513. https://doi.org/10.1016/j.lwt.2015.11.09

Goniet, I., García-Alonso, A. & Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research*, *17*(3), 427-437. https://doi.org/10.1016/S0271-5317(97)00010-9

Inchuen, S., & Duangkhamchan, W. (2021). Effects of operating conditions on quality attributes of instant brown rice porridge prepared by microwave assisted foam-mat drying. *Engineering and Applied Science Research*, *48*(6), 677-683.

Jantawan, W. (2022). *The queen of green*. Retrieved from https://kb.mju.ac.th/article.aspx?id=1374

Joshi, L. & Jadeja, G. (2017). Amylase rich porridge effect on geriatric health. *Gujarat Journal of Extension Education*, *28*(2), 257-260.

Kandasamy, P., Varadharaju, N., & Kalemullah, S. (2012). Foam-mat drying of papaya (Carica papaya L.) using glycerol monostearate as foaming agent. *Food Science and Quality Management*, *9*(1), 17-27.

Kebngoen, C. (2019). *Development of instant powdered beverage from washing Riceberry water* [Unpublished doctoral dissertation or Unpublished master's thesis]. Rajamangala University of Technology Thanyaburi.

Lerdluksamee, C., Srikaeo, W., & Srikaeo, K. (2024). Glycemic responses of special rice: Case study in Thai geographical indication rice cultivars. *Agriculture and Natural Resources*, *58*(1), 13-22. https://doi.org/10.34044/j.anres.2024.58.1.02

Mounir, S. (2018). Foam Mat Drying FMD. In Nema, P.K. (Eds.), *Drying Technologies For Foods: Fundamentals And Applications* 1ed., pp. 169-191). Retrieved from https://www.researchgate.net/publication/320566592_Foam_Mat_Drying_FMD

Munlum, S., & Junsi, M. (2024). Production of Kaeng Liang Soup (Thai Style Spicy Mixed Vegetable Soup) powder using foam-mat drying. *Journal of Current Science and Technology,14*(1), Article 13. https://doi.org/10.59796/jcst.V14N1.2024.131

Nethathe, B., Matsheketsheke, P. A., Mashau, M. E., & Ramashia, S. E. (2023). Microbial safety of ready-to-eat food sold by retailers in Thohoyandou, Limpopo province, South Africa. *Cogent Food & Agriculture*, *9*(1), Article 2185965. https://doi.org/10.1080/23311932.2023.2185965

Nitikornwarakul, C., Wangpradid, R. Sirimuangmoon, C., Lekjing, S., Nishioka, A. & Koda, T. (2022). Nutritious elderly diet: Pigmented rice-porridge from shear-heat milling process. *Italian Journal of Food Science*, *34*(3), 25–34. https://doi.org/10.15586/ijfs.v34i3.2241

Niyomwet, P., Sappasit, P., Waree, A., & Khongsit, P. (2018). Product Development of Instant Riceberry Porridge. *Burapha Science Journal*, *23*(3), 1638-1654.

Qadri, O.S. & Srivastava, A.K. (2014). Effect of microwave power on foam-mat drying of tomato pulp. *International Agricultural Engineering Journal*, *16*(3), 238-244.

Reda, T., Thavarajah, P., Polomski, R., Bridges, W., Shipe, E. & Thavarajah, D. (2021). Reaching the highest shelf: a review of organic production, nutritional quality, and shelf life of kale (*Brassica oleracea* var. *acephala*). *Plants People Planet*, *3*(4), 308–318. https://doi.org/10.1002/ppp3.10183

Reis, F. R., de Moraes, A. C. S., & Masson, M. L. (2021). Impact of foam-mat drying on plant-based foods bioactive compounds: a review. *Plant Foods for Human Nutrition*, *76*(2), 153-160. https://doi.org/10.1007/s11130-021-00899-3

Saentaweesuk, S. (2012). *A production of Indian gooseberry instant powder by Foam-mat drying* [Conference presentation]. Kasetsart University Annual Conference, Kasetsart University, Thailand.

Sangamithra, A., Sivakumar, V., Kannan, K., & John, S. G. (2015). Foam-mat drying of muskmelon. *International journal of food engineering*, *11*(1), 127-137. https://doi.org/10.1515/ijfe-2014-0139

Senadheera, S. & Ekanayake, S. (2013). Development of a marketable rice based herbal porridge suitable for diabetics from *Scoparia dulcis. Agricultural Sciences*, *4*(9B), 81-84. https://doi.org/10.4236/as.2013.49B014

Sifat, S. A. D., Trisha, A. T., Huda, N.**,** Zzaman, W**.** & Julmohammad, N. (2021). Response surface approach to optimize the conditions of foam mat drying of plum in relation to the physical-chemical and antioxidant properties of plum powder. *International Journal of Food Science*, *2021*, Article 3681807. https://doi.org/10.1155/2021/3681807

Thai Industrial Standards Institute Ministry of Industry. (2021). *Thai Industrial Standard (315-2021): Instant Rice Porridge.* Retrieved from https://service.tisi.go.th /tisi-standard-shop/item/tis/5374

Thuwapanichayanan, R., Prachayawarakorn, S., & Soponronnarit, S. (2008). Drying characteristics and quality of banana foam mat. *Journal of food engineering*, *86*(4), 573-583. https://doi.org/10.1016/j.jfoodeng.2007.11.008

Thuy, N. M., Tien, V. Q., Van Tai, N., & Minh, V. Q. (2022). Effect of Foaming Conditions on Foam Properties and Drying Behavior of Powder from Magenta (*Peristropheroxburghiana*) Leaves Extracts. *Horticulturae*, *8*(6), Article 546. https://doi.org/10.3390/horticulturae8060546