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Effects of foaming agent types and ratio with red flesh pitaya puree on physicochemical properties of foam-mat dried powder

Tengku Nur ‘Aisyah Afifah Binti Tengku Ahmad Akman, Norzaida Yusof*, Nurul Zaizuliana Rois Anwar and Tengku Farizan Izzi Che Ku Jusoh

School of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia

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⌧*Corresponding author:
Dr.Norzaida Yusof
School of Food Industry, Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200 Besut, Terengganu, Malaysia.
Email: norzaida@unisza.edu.my

Abstract

Red flesh pitaya (Hylocereus sp.) is a highly perishable fruit with a high content of bioactive compound. It has short shelf life due to high moisture content and water activity. In this study, red flesh pitaya (RFP) powder was produced via foam mat drying method (FMD) with egg albumen (EA) and whey protein isolate (WPI) as the foaming agents. This study aimed to investigate the effect of foaming agent types and its ratio with RFP puree on physicochemical properties of foam-mat dried RFP powder. RFP fruit was incorporated and foamed with EA and WPI at 0 %, 5 %, 15 % and 30 % w/w concentrations. The foam was dried at 65 ˚C for 5 hours. The powders were analysed for its moisture content, water activity, solubility, density, colour, fiber and total soluble solid (TSS). Decreasing the puree concentration from 85% to 55% while increasing the concentration of foaming agents (0% to 30%) has decreased the value of moisture content, water activity, crude fiber and colour properties. Meanwhile, the solubility, density and TSS of the foam-mat dried RFP powder was increased with increasing the concentration of both foaming agents (decreasing the ratio of RFP puree) used. The quality of powder foamed with WPI has produced the lowest in moisture content (2.86 %) and water activity (0.18), high in solubility (71.03 %), densities (0.56 g/cm3 and 0.84 g/cm3) and high in TSS (9.61). Meanwhile, the quality of samples foamed with 5% EA and 80% of RDF puree observed high in fiber content (3.38 %) and mostly retains the colour properties. FMD technique may be applied as the preservation technique of fruit powder as it has produced the powder with low moisture content and good colour properties within a short time and is more economical.

1. INTRODUCTION

Pitaya also known as dragon fruit, originates from Mexico, Central and South America, and is commercialized in Vietnam, Australia, and Taiwan. The fruit is classified according to its flesh and skin colour; red flesh with red skin, white flesh with red skin, and white flesh with yellow skin. Among the fruits, red flesh and skin are widely consumed due to their high content of phenolic compounds that act as antioxidants. Red pitaya has been an important ingredient in a variety of food products, including juice, yogurt, ice cream, baked goods, food colouring, and confectionery products (Huang et al., 2021). Red pitaya has also created interest in the food industry area due to its use as an economical, environmentally friendly, plant-based, and clean-label ingredient (Michelle et al., 2017). However, red flesh pitaya (RFP) fruit is considered as one of the fruits that is highly perishable, due to its high moisture content value. A study by Choo et al. (2018) states that fresh red pitaya fruit can only last a maximum of 14 days at 10 °C and 5 days at room temperature, which is relatively short compared to other fruit.

Drying method is widely used to preserve fruit and vegetables involves fruit powder production. It is a process of removing the moisture content in the food materials to improve the shelf life and prevent microbial growth. The application of this method in food systems can induce the loss of temperature or heat sensitive compounds, denaturation of proteins, changes in the food structures, modifying the colour and taste and also may present new undesirable elements (Estupiñan-Amaya et al., 2020). Thus, selection of the best drying method is important to produce high quality of fruit powder. Various methods have been applied in the production of fruit powder which includes spray drying, freeze drying, microwave drying, drum drying and foam-mat drying. According to Ishwarya et al. (2015), spray drying method can cause the degradation of qualities of finished product due to very high temperature. Meanwhile, for the freeze drying, it was more time consuming and expensive method. However, there are still limited studies on the production

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of the red flesh pitaya powder produced via foam-mat drying (FMD) method.

Foam mat drying method is considered as an innovative technology in food powder production. The method was applied by transforming the food material or fruit into the foam structure with the incorporation of foaming agents to easily dry the surface prior to the drying (Ishwarya et al., 2015). Foam mat drying process is reported to be less costly, more convenient, and associated with low deterioration of product quality compared than other drying method (Tan & Sulaiman, 2020). Selection and the concentration of the foaming agent used gives influence to the product quality produced. Egg albumen and whey protein isolate are the common types of foaming agents used to produce the powder by FMD method. Both egg albumen and whey protein isolate are the foaming agents that known for their rich in protein contents.

Currently, there is limited study regarding the foam mat drying (FMD) method with different types of foaming agent used to produce the RFP powder. Thus, the aim of this study was to investigate the effect of foaming agent types and its ratio with red flesh pitaya (RFP)the puree on physicochemical properties of foam-mat dried red flesh pitaya powder. The optimum conditions to produce the RFP powder with good physicochemical properties was also obtained.

2. MATERIALS AND METHODS

2.1. Materials and chemicals

Fresh ripe red pitaya, (RFP) were bought from a local market at Pulau Kerengga, Marang, Terengganu, and was selected based on size and skin colour (red) uniformity. The egg white albumen, EA (foaming agent) was purchased at the Local Market in Besut, Terengganu. Whey protein isolate, WPI (foaming agent) and maltodextrin, MD (foam stabilizer) was provided by the Laboratory of University Sultan Zainal Abidin.

2.2. Foam mat drying process

Red pitaya fruit was washed with running tap water to remove undesirable external material. Then, the peel was removed manually by using a stainless steel knife. The fruit was cut into small cube pieces and ground using food processor to turn into puree. For the foaming agent preparation, the EA was extracted from the whole egg. Then, the RFP fruit puree was whipped with different concentrations of EA and WPI (0, 15 and 30 % wt/wt) for 15 mins of whipping time with maximum speed (1200 rpm) by using the hand-mixer. 15 % wt/wt of MD with DE 10-12 was added as a foam stabilizer. Table 1 represents the sample formulations. The foam-mat drying (FMD) of pitaya puree was prepared according to method by (Hossain et al. (2021) with some modification. The foamed pitaya puree was poured and spread in a tray (stainless steel), before placed in cabinet tray dryer at 65 ˚C for 5 h with constant air velocity. After drying was done, the dried materials were ground into powder and packed in an aluminium pouch bag. The samples were stored at room temperature until further analysis.

Table 1: Sample formulation for the production of red pitaya (RFP) powder

Foaming Agent	Formulation		
	Foaming Agent (%)	**RFP Puree (%)**	**Maltodextrin (%)**
CN	0	85	15
EA	5	80	15
	15	70	15
	30	55	15
WPI	5	80	15
	15	70	15
	30	55	15

CN= Control, EA= Egg Albumen, WPI= Whey Protein Isolate

2.3. Determination of moisture content

Moisture content of dried powder was determined by oven drying at 105°C (AOAC, 1995).

2.4. Determination of water activity

The water activity of RFP powder was determined by using AquaLab Dew Point Water Activity Meter (Decagon Devices, WA, USA) at 25 ˚C. Firstly, the water activity meter was calibrated by using distilled water for its accuracy. Next, 2 g of samples were weighed and evenly placed into the plastic cells and was allowed to equilibrium within the headspace of the sealed chamber. The reading was recorded in triplicates when equilibrium was achieved.

2.5. Determination of bulk and tapped densities

The bulk density of foam-mat dried RFP powder was determined according to the method of Saifullah et al. (2016). 2.5 g of pitaya powder was transferred to a 10 mL graduated cylinder without tapping and disturbance. Then, the volume occupied by the sample was recorded. The analysis was carried out triplicates and bulk density was calculated based on Eqn. 1.

$$\text{Bulk Density (g/cm}^3) = \frac{\text{Weight of powder}}{\text{Volume occupied by the powder}} \quad \text{Eqn.1}$$

Tapped density of the powder was determined by manually tapped method. 2.5 g of foam-mat dried RFP powder was filled into the test tube, and the tapping was operated at a fixed number of taps (100 taps) until reached a constant volume. The analysis was carried out triplicates. Then, the tapped density was calculated according to the Eqn. 2.

$$\text{Tapped Density (g/cm}^3) = \frac{\text{Weight of powder}}{\text{Volume occupied by the powder}} \quad \text{Eqn.2}$$

2.6. Determination of solubility

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Solubility of foam-mat dried RFP powder was determined based on method by Yusof et al. (2022) with some modification. 1 g of powder was vigorously mixed with 25 ml of distilled water in a 50 ml of centrifuge tube for 5 min, using a magnetic stirrer. The mixture then was centrifuged at 3000 x g at 25 °C for 10 min. Next, a total of 20 mL of supernatant was transferred into a pre-weighed petri dish and oven-dried at 105 °C for overnight. The percentage of solubility was determined based on Eqn. 3.

$$\% \text{ Solubility } = \frac{\text{Weight of dried residue}}{\text{Weight of original powder}} \times 100 \qquad \text{Eqn.3}$$

2.7. Colour analysis

The colour of foam-mat dried RFP powder was determined by using a Colorimeter (Konica Minolta CR-400, Japan) at 25 ˚C. The instrument was calibrated with standard white tiles before analysis. The outcome results were expressed as Hunter colour values based on L*, a* and b* value, where the L* value is used to presents the lightness (+) and darkness (-), a* value used to present the redness (+) and greenness (-), and the b* value presents yellowness (+) and blueness (-). All the reading of colour was performed triplicates.

2.8. Determination of crude fiber content

Crude fiber content for fresh and dried powders were analyzed according to AOAC methods (1995).

2.9. Determination of total soluble solid, TSS (˚Brix)

TSS of foam-mat dried RFP powder was measured by using a digital refractometer (DeltaTrak, USA). The digital refractometer was calibrated first with distilled water before the measurement. A drop of the sample was placed on the refractometer's sample port and the measurement was recorded. The analysis was performed in triplicates.

2.10. Statistical analysis

The results were presented as mean values and standard deviation. The difference mean values were analysed by analysis of variance (ANOVA) one-way and Duncan's test (p-value < 0.05) to establish the significance of differences among the mean values by using statistical software SPSS 20.

3. RESULTS AND DISCUSSION

3.1. Physicochemical properties of foam-mat dried RFP powder

Table 2 shows the results for moisture content and water activity of foam-mat dried RFP powder. Based on the table 2, there were significantly difference ($p < 0.05$), in the moisture content of control sample compared to other foam-mat dried RFP powder. The control has the highest moisture content (9.19 ± 0.08 %) compared to others. As the fruit is highly perishable and high in moisture content, thus the high percentage of puree in control sample has cause high moisture content in the powder. However, decreasing the concentration of puree while increase the foaming agent concentrations has led to a decrease in moisture content values.

Table 2: Moisture content and water activity of foam-mat dried RFP powder

Foaming Agent	Foaming Agent (%)	Red Flesh Pitaya Puree (%)	Moisture Content (%)	Water Activity (a_w)
CN	0	85	9.19 ± 0.08^a	0.54 ± 0.01^a
EA	5	80	6.78 ± 0.01^b	0.35 ± 0.01^b
	15	70	5.05 ± 0.10^c	0.34 ± 0.02^b
	30	55	3.52 ± 0.45^e	0.32 ± 0.01^c
WPI	5	80	4.40 ± 0.00^d	0.25 ± 0.00^d
	15	70	4.22 ± 0.09^d	0.20 ± 0.00^e
	30	55	2.86 ± 0.23^f	0.18 ± 0.01^e

The results comprise mean ± standard deviation. Different letters in the same column indicates significantly different ($p < 0.05$), n = 2.

This result shows that, without the foaming agent, the moisture content of the foam-mat dried RFP powder is high, as the foaming agent plays an important role in providing the foam structure to increase the drying rate. This is because the foam structure that is formed by foaming agents has a large surface area and a porous structure. This condition can increase the drying rate and decrease the moisture content of the sample. According to Chaux-Gutiérrez et al. (2017), the foam structure has increased the evaporation surface, improving the drying process. The FMD process provides a relatively high drying rate because of the large surface exposed to the drying air, ensuring fast moisture removal. Other than that, the form properties of the foaming agent also influence the moisture content. The WPI are present in the solid form of powder, whereas the EA foaming agent is present in the semi-liquid form. Thus, the properties of WPI powder contribute to the lower moisture content. This property of the foaming agent indicates that WPI can cause a lower moisture content, thus promising a longer shelf life of the foam-mat dried RFP powder.

Water activity is also indeed an important property of powders as it was a greatly have an effect on the shelf life of powder. According to the table 2, the water activity recorded for all samples were between the ranges of 0.54-0.18. Izadi et al. (2020) reported that food with water activity less than 0.6 is microbiologically stable. The results shows that the all foam-mat dried RFP powders were highly stable and has low chance to being spoiled

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with the microorganisms growth. For comparing the water activity between the samples, there were significantly difference ($p < 0.05$) between the water activity recorded for the control sample as it was higher than other samples with foaming agents. This property indicates that foaming agent highly influences the water activity properties of the powder. Study by Shaari et al. (2018) also has showed the same trend with this finding. The water activity recorded for the 0 % of foaming agent was 0.54 higher than the sample prepared with foaming agent.

Next, it can be observed that increase in concentration of foaming agents has cause decreased in the water activity value of RFP powder. This is probably due to the increase in the drying rate with increasing concentration. High concentration causes the increase in the drying rate as the properties of addition the foaming agent that give the porous structure has reduced the water activity. Not only that, increase the concentration of foaming agent also cause decrease in the RFP puree used. Thus, this also contributes to the low water activity as the percentage of highly perishable fruit has been decreased. For the effect of different types of foaming agents, there was a significant difference between the samples foamed with WPI and EA. The results achieved because of the incorporated properties of the WPI that cause a lower water activity compared to EA.

Density is an important property of food powder products. According to Ezzat et al. (2020), bulk and tapped densities are among physical properties that important to measure and define the volume of the solid and liquid materials and all closed and opened pores. Table 3 shows the results for bulk and tapped densities of foam-mat dried RFP powder.

Based on the table 3, the bulk density of the powders was in the range of 0.37 g/cm3 to 0.56 g/cm3. Meanwhile, for tapped density, the range value recorded was between 0.55 g/cm3 to 0.84 g/cm3. There were significantly difference between the control with others sample powder as it has recorded the lowest bulk and tapped densities compared to other samples. As the ratio of foaming agents has increase, the ratio of puree was decreased and has results high in density value for the powder samples. Similar trend also been reported by Michalska and Lech (2018) which observe increased in bulk density (0.53 g/cm3 - 0.61 g/cm3) of apple juice powders when the concentration of carrier agents was increased. Another similar trend observed for the study by Yükse (2021) for the yoghurt powder that using microwave-assisted foam mat drying. According to Yükse (2021), the density of the powder may be influenced by the properties of foaming agents. Mainly, increase the concentration of foaming agents has cause increase in the solid content. When more solids present, there is greater amount of material that packed into a given volume. This condition has resulted in increased density values. Fauziyah et al. (2023) also reported that the increasing bulk density with increasing the concentration foaming agent was due to the less crystallization at high concentration.

For the effects of foaming agents, powder foamed with WPI recorded higher densities value for both bulk and tapped densities compared to powder foamed with EA. The differences in results may due to the different in protein properties of foaming agent. It was reported that WPI has high content of protein compared with EA. The higher protein content has contributed to the higher density of WPI. Other than that, the processing method for foaming agent may has influences on the density of powder. Generally, WPI was produced through various filtration and purification process to purify the protein content and typically removing the water and other non-protein content, resulting in more concentrated powder. Meanwhile, EA is a protein that mainly composed with mixture of protein, water and may include other components. Thus, the less concentrated of EA has led to a lower bulk density compared to WPI. Darniadi et al. (2020) reported that bulk density of food powder targets has to be met to provide the consistent weight during packaging, warehousing and transportation.

Table 3: Bulk and tapped density of foam-mat dried RFP powder

Foaming Agent	Foaming agent (%)	Red Flesh Pitaya Puree (%)	Bulk Density (g/cm^3)	Tapped Density (g/cm^3)
CN	0	85	0.37 ± 0.01^{d}	0.55 ± 0.01^{f}
EA	5	80	0.44 ± 0.02^{c}	0.66 ± 0.00^{e}
	15	70	0.52 ± 0.01^{b}	0.70 ± 0.00^{d}
	30	55	0.55 ± 0.01^{a}	0.75 ± 0.03^{bc}
WPI	5	80	0.52 ± 0.02^{b}	0.72 ± 0.02^{cd}
	15	70	0.54 ± 0.01^{ab}	0.77 ± 0.03^{b}
	30	55	0.56 ± 0.01^{a}	0.84 ± 0.00^{a}

The results comprise mean ± standard deviation. Different letters in the same column indicates significantly different ($p < 0.05$), n = 3.

Solubility is one of the important properties of powder that can influence the powder quality. It is a representative of powder behavior in an aqueous phase. Table 4 shows the results for the solubility analysis of foam-mat dried RFP powder. Based on table 4, there were significantly difference ($p < 0.05$), observed for solubility between the control and RFP foam mat powder dried with EA and WPI as foaming agents. The solubility recorded for the control (CN) was the lowest (46.23 ± 5.76) compared to other RFP foam mat dried powder which solubility were reported in the range from 56.98 ± 0.05 to 71.03 ± 0.04. These findings were similar with findings reported by Gao et al. (2022) on the solubility of foam-mat dried blueberry pulp powder. The solubility for sample control (51.56 ± 0.77) was significantly lower than blueberry powder samples dried with egg white powder as foaming agent (62.22 – 80.00 %). Thus, this proved that the addition of foaming agents helps improve the solubility of foam-mat dried powder. However, based on the table, decreasing the ratio of sample with RFP puree with increase ratio of foaming agent concentration has results in high solubility of samples powder. This is because the properties of foaming agents have influenced the solubility. Mainly, the protein consists with hydrophilic regions that provide the interaction with water molecules. When the concentration of the foaming agent is increased, more hydrophilic sites are available for water to interact with, thus promoting better solubility. Similar trend has been reported by Chandrasekar et al. (2015) for the effect of increase the concentration of foaming agent on solubility of foam-mat dried mixed vegetable. The researchers reported that increasing the concentration of foaming agent will increase the surface area of the foamed juice through more incorporation of air.

Table 4 Solubility properties of foam-mat dried RFP powder

Foaming Agent	Concentration Foaming Agent (%)	Red Flesh Pitaya Puree (%)	Solubility (%)
CN	0	85	46.23 ± 5.76[e]
EA	5	80	56.98 ± 0.05[d]
	15	70	61.64 ± 0.36[cd]
	30	55	65.93 ± 0.92[abc]
WPI	5	80	64.59 ± 0.76[bc]
	15	70	69.32 ± 0.13 [ab]
	30	55	71.03 ± 0.04[a]

The results comprise mean ± standard deviation. Different letters in the same column indicates significantly different ($p < 0.05$), n = 2.

Comparing the different foaming agent used, samples foamed with WPI were reported higher solubility compared to the samples foamed with EA. Solubility of the powder may has affected by several factors including the protein composition or type of amino acids and protein structure (Yousefi & Abbasi, 2022). However, the solubility of powder may be varied and preferred according to its intended use. Compared to the existing studies of FMD method, the solubility observed from this finding was higher compared with the solubility of foam-mat dried sour cherry powder (solubility 43 – 48 %) that foamed with foaming agents of EA and methylcellulose (Abbasi & Azizpour, 2016). Other findings by Belal et al. (2023) for the solubility of foam-mat dried tomato powder, the values were ranged 39.92 % - 43.25 %. Affandi et al. (2017) also reported the solubility of foam-mat dried nigella sativa beverage powder within the range 25.45 % to 55.45 %. It was observed that, the preferred solubility of powder was depending on the intended use of application. Findings by Roongruangsri and Bronlund (2016) reported that, the solubility value of pumpkin powder that high than 50 % was considered as good quality of powder as it may be applied in baking purpose.

The colour properties of the RFP powder was the important attributes of their quality concerning the powder as natural colourant agent. Table 5 shows the results of colour properties of foam-mat dried RFP powder. Based on the table 5, it was revealed that the colour properties for lightness value, (L*) of all samples were significantly different ($p < 0.05$). This was due to the influence with the ratio of increase concentration of foaming agent with decrease amount of RFP puree. The control sample for foam-mat dried RFP powder has the lowest L* value which indicates low in the lightness. This is due to the high ratio of RFP puree used with no addition of any foaming agent into the sample. Thus, the high percentage of the RFP puree used has contribute to the increase in darker colour (Figure 1).

Table 5 Colour properties of foam-mat dried RFP powder

Foaming Agent	Foaming agent (%)	RFP Puree (%)	L*	a*	b*
CN	0	85	40.91 ± 0.50[g]	20.38 ± 0.37[f]	1.46 ± 0.24[g]
EA	5	80	49.07 ± 0.06[f]	34.46 ± 0.08[a]	-3.58 ± 0.03[e]
	15	70	55.40 ± 0.03[e]	28.71 ± 0.05[b]	-4.66 ± 0.03[d]
	30	55	67.69 ± 0.59[b]	25.81 ± 0.21[d]	-5.28 ± 0.03[b]
WPI	5	80	57.67 ± 0.06[d]	28.79 ± 0.05[b]	-7.15 ± 0.02[a]
	15	70	61.30 ± 0.06[c]	27.35 ± 0.20[c]	-5.11 ± 0.02[c]
	30	55	73.44 ± 0.13[a]	21.76 ± 0.07[e]	-1.69 ± 0.03[f]

The results comprise mean ± standard deviation. Different letters in the same column indicates significantly different ($p < 0.05$), n = 3.

However, the colour properties of foam-mat dried RFP powder with the increasing concentration of foaming agents of EA and WPI while decreasing the concentration of RFP puree had significantly increase the value of the lightness, (L*). This is because, as the concentration of foaming agents increased, the percentage puree of RFP used was decreased. Thus, the corporation of the colour properties from the RFP fruit has been decrease. This trend also similar with the finding Tan & Sulaiman (2020) on the colour and rehydration characteristics of natural red colourant of foam-mat dried *Hibiscus sabdariffa* L. powder. According to the researchers, increase in the L* value of the powder was due to the addition of EA which contributes to white colour. Thus, the increase in L* value contributed with the colour properties of foaming agents used. Generally, EA foaming agent was white in colour, meanwhile for the WPI was in yellowish colour. Thus, the contribution on these colour properties of foaming agents with low ratio of RFP puree used had caused increase in the L* values. This also can be supported by the similar results obtained by Ng and Sulaiman (2017) on the foam-mat dried beetroot (*Beta vulgaris*) powder.

Comparing the powders foamed with different types of foaming agents, powder samples with EA has produced low *L values compared to the WPI foamed powders. The difference of results was because as the EA, a semi liquid compounds and white in colour, it can more retains the red colour of RFP powder. Meanwhile, WPI added was in a solid form (powder) and yellowish in colour. Thus, the combination of colour properties for WPI and puree has caused more increase in *L value towards the powder. Next, for the a* value that indicates the redness of the foam-mat dried RFP powder, there was a significant difference between the control sample 0 % of foaming agent and 5, 15 and 30 % of foaming agent. The control sample (0 % of foaming agent) had the lowest a* value which was 20.38, meanwhile sample foamed with 5 % EA had the highest a* value. Generally, when high ratio of RFP puree used with low concentration of foaming agents, it will result high in a* value. However, the difference of the results may be related with the darker colour of the powder produced. This properties can be supported with the findings by Hajuaghaei and Sharifi (2022) for the colour properties of powder of red beetroot and quince fruit extracts. In these researchers findings, it was observed that the highest a* value obtained for the powder contains 20 % maltodextrin (MD) compared with 10 % MD. According to the researchers, this properties due to the high amount of red pigments that appeared dark when the colour of its surface was measured which gives low L*, so lower value of a* recorded. Thus, for the foam-mat dried RFP powder, the lower a* values of control sample may be due to the high amount of red pigments that appeared dark as the samples also recorded low in L* value.

Figure 1 Colour properties of foam-mat dried RFP powder. (a) Concentration of foaming agent 0 %, (b): RFP powder with 5% EA, (c) RFP powder with 15% EA, (d) RFP powder with 30% EA, (e) RFP powder with 5% WPI, (f) RFP powder with 15% WPI and (g) RFP powder with 30% WPI

Meanwhile, the increasing concentration of EA and WPI with decreasing the RFP puree ratio caused the decrease for the a*. This can be seen for the samples foamed with EA records 34.46 ± 0.076, 28.71 ± 0.047, 25.81 ± 0.21 respectively for increasing concentration of EA used. Same trend also can be seen for increasing concentration of WPI which results 28.79 ± 0.05, 27.35 ± 0.20, 21.76 ± 0.067 respectively in a* value. The results due to the increase concentrations of foaming agents and decreased the ratio of RFP puree used and also due to the corporation of colour properties of foaming agents. For the different types of foaming agents used, samples foamed with EA foaming agent gives a high a* value compared to the WPI foaming agent. This property resulted as EA is a foaming agent that whitish in colour meanwhile, WPI was yellowish in colour. The collaboration between the EA colour and puree colour had given high value of redness compared with WPI.

The b* values recorded for the all samples was significantly different at $p < 0.05$. It was observed that, the control sample that has high ratio of RFP puree with no foaming agent resulted in yellowness in b* meanwhile blueness value observed for other samples. The difference of b* value recorded among the samples was due to the high ratio of RFP puree and the addition foaming agent. Basically, for the control sample that high ratio in RFP puree with low ratio of foaming agents cause yellowness in colour. When exposed with the hot air drying, the degradation of betacyanin pigment has occurred. It was reported by Pamungkas et al. (2020) that upon heating, betacyanin was found to decompose into yellow degradation products, which led to decrease in red values (a*) while increase in the yellow (b*) colour. However, increasing the concentration of foaming agents of EA with decrease the ratio or RFP puree has caused increase in b* values for blueness. Meanwhile, for WPI, increasing the concentration of WPI and decreasing the ratio of RFP puree had caused the decreased in the b* values of blueness. The differences between these results were due to the different properties of foaming agents used. For WPI, the yellowish colour of this foaming agent had cause the powder to decrease in colour properties of blueness, while, the colour provide by EA had caused the powder has the increase b* values of blueness due to the combination of colour.

Determination of crude fiber of foam-mat dried RFP powder was important, as it was the main nutritional properties of RFP. Table 6 shows the results for the crude fiber and TSS for foam-mat dried RFP powder.

Table 6 Crude fiber and TSS of foam-mat dried RFP powder

Foaming Agent	Foaming Agent (%)	Red Flesh Pitaya Puree (%)	Crude Fiber (%)	Total Soluble Solid, TSS (°Brix)
CN	0	85	4.83 ± 0.19^{a}	7.69 ± 0.13^{c}
EA	5	80	3.38 ± 0.16^{b}	7.93 ± 0.32^{c}
	15	70	2.65 ± 0.07^{d}	9.25 ± 0.04^{b}

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	30	55	0.67 ± 0.19[e]	9.31 ± 0.04[b]
WPI	5	80	2.95 ± 0.01[c]	9.24 ± 0.08[b]
	15	70	0.82 ± 0.02[e]	9.33 ± 0.11[b]
	30	55	0.18 ± 0.02[f]	9.61 ± 0.04[a]

The results comprise mean ± standard deviation. Different letters in the same column indicates significantly different (p<0.05), n = 2 for crude fiber; n = 3 for TSS.

From table 6, there were significantly difference ($p < 0.05$) between the control sample with foam-mat dried RFP samples. The crude fiber content obtained for control sample powder recorded the highest among the samples with 4.83 ± 0.19 % compared to other powder samples. This is because, RFP is a fruit that known high in fiber content (Susanti et al. 2022). Thus, due to the high in ratio of RFP puree with no foaming agents added, it results in high crude fiber content for control sample. Meanwhile, for the effect of ratio between foaming agents and RFP puree, there were significantly difference ($p < 0.05$) observed for the powder with the decreasing ratio of RFP puree while increasing the ratio of foaming agents. Samples with high ratio of foaming agent and low of RFP puree has results decrease amount of crude fiber content.

Comparing the effects of different foaming agents, samples foamed with EA have a higher fiber content compared with samples foamed with WPI. However, both of the foaming agents, EA and WPI are the foaming agents that high in protein content with relatively low fiber content for EA and may contain negligible amount of fiber in WPI. For WPI, it highly refined form of whey protein, with majority of fats, lactose and other non - protein components removed and mainly composed with highly of protein content. The high amount of fiber observed for the samples foamed with EA compared to WPI was due to the dilution effect. Similar effect of decrease in biochemical properties of foam mat dried sour cherry powder was observed from the studies by Abbasi and Azizpour (2016).

Based on the table 6, there was significant difference ($p < 0.05$) between the foam-mat dried RFP control powder with other samples powder except for the sample powders foamed with 5 % of EA. TSS value for the foam-mat dried RFP control sample observed has the lowest value with 7.69 ˚Brix. This is because the control samples are mainly containing with the puree and 0 % of foaming agents. Due to high moisture content properties of RFP puree, thus, it gives the low TSS value as low amount of soluble solids represent in the puree for control sample. The water content in the puree was considered as a solvent as in which the soluble solids are dissolved.

Comparing the effect of ratio RFP puree and foaming agent, it was observed that increasing the concentration of both foaming agents while decreasing the RFP had caused increase in TSS value. For samples foamed with EA, the TSS value ranged from 7.93 ± 0.32, 9.25 ± 0.04 and 9.31 ± 0.04, respectively. Meanwhile for the foaming agent of WPI, the TSS value observed for foam-mat dried RFP were 9.24 ± 0.08, 9.33 ± 0.11 and 9.61 ± 0.04. This is because, by increased the percentage or concentration of foaming agents, there were also increase in the component which protein, provided by the foaming agent, and cause increase in TSS value. Similar result was obtained by Hossain et al. (2021), on the effect of foaming agent concentration (EA) on biochemical properties of foam-mat dried tomato powder. The researchers reported that, the increasing value of TSS with increasing concentration of foaming agent was caused by some inherent component in foaming agents which mainly composed with high protein content.

For the effect of different foaming agents, it was observed that foam-mat dried RFP powder incorporated with WPI had the high value of TSS compared to the samples foamed with EA. The differences between the results mainly because of the properties of WPI that highly in protein content compared to the EA. It is known that WPI is derived from whey, a by-product of cheese production. The whey has been undergoing filtration and processing process to remove most of the non-protein components which includes the lactose and fat. Thus, the foaming agent of WPI are mainly composed with the high protein contents that contribute to the high TSS value. Meanwhile, EA is a protein component of egg and contain a significant amount of water. Thus, the presence of the water has lowered the TSS value of foam-mat dried RFP powder foamed with EA compared to WPI.

4. CONCLUSION

As conclusion, the production of RFP powder by FMD method has successfully produced in this study. The effects of foaming agent types and its ratio with RFP puree on foam-mat dried RFP powder were determined. Based on the result, FMD method has physically influence the product, and producing the best properties of powder which is low in moisture content, water activity, and has a great quality on the colour properties of the powder. It was observed that, increase concentration of foaming agent has caused low moisture content and water activity, and also decreases the fiber content of the powder. The solubility and TSS of powder increased as the concentration of foaming agents increase. In terms of types foaming agent, WPI was significantly produced the good quality of powder based on the moisture content and water activity. However, comparing with EA foaming agents, the EA has provided the good quality of RFP powder by retaining the colour properties and also high in fiber content. For future recommendation, antioxidant and betacyanin content were also recommended to determine for future studies. Overall, FMD is a technique that combines the benefits of foam formation and drying, offering an effective and efficient

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method for moisture removal while preserving the quality of food products.

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