PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.1913

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Impact of foaming conditions on quality for foam-mat drying of Butterfly pea flower by multiple regression analysis

Nguyen Minh Thuy[1*], La Bao Phung[1], Ngo Van Tai[2] & Vo Quang Minh[3]

[1]Institute of Food and Biotechnology, Can Tho University, Can Tho 900000, Vietnam
[2]School of Food Industry, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
[3]College of Enviroment and Natural Resources, Can Tho University, Can Tho 90000, Vietnam

*Email: nmthuy@ctu.edu.vn

OPEN ACCESS

ARTICLE HISTORY

Received: 25 May 2022
Accepted: 11 November 2022

Available online
Version 1.0 : 14 January 2023

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS etc.
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Thuy N M, Phung L B, Tai N V, Minh V Q. Impact of foaming conditions on quality for foam-mat drying of Butterfly pea flower by multiple regression analysis. Plant Science Today (Early Access). https://doi.org/10.14719/pst.1913

Abstract

In recent years, the Butterfly pea flower has been increasingly interested in its color and function. However, the preservation of the extract faced many difficulties; therefore, foam drying technology was applied to solve this problem. The study was conducted to determine the effect of foaming conditions, including albumin ratio, carboxymethyl cellulose (CMC) ratio, and whipping time on foam characteristics. At the same time, the multi-dimensional regression method was also used to determine the most suitable foaming conditions for the following process. The research results showed that all 3 factors strongly influenced the foaming process of pea flower extract. It could be concluded that the most suitable condition for foaming is to use 9.3% albumin, 0.79% CMC and stir for 19 min. Under these conditions, the foam expansion and stability were 584.79% and 96.44% respectively. The powder obtained from the foam drying of Butterfly pea flower extract was also analyzed for quality. The temperature of 65 °C for 4 hrs gave relatively high-quality powder with protein content, anthocyanin and antioxidant activity of 9.89 g/100g, 1.15 mg/g and 87.34% respectively. In conclusion, the foam-mat dried powder from butterfly pea flower extract is suitable for other processing processes, especially in the processing of folk cakes, pasta and bread industry.

Keywords

foam-mat drying, Butterfly pea flower, foaming conditions, foam characteristics

Introduction

The Butterfly pea flower (*Clitoria ternatea)* is considered a medicinal herb (1), playing an essential role in neuro medicine as well as improving the brain system and memory when incorporated with other parts (2) and supporting treatment for people with mental illness (3). The primary color of butterfly pea flowers is blue, traditionally used as a food colorant. The blue pigment of Butterfly pea flower is anthocyanin, which has the great potential to be used as a natural blue colorant for foods, cosmetics and pharmaceuticals at neutral pH. Anthocyanins are compounds belonging to the flavonoid family, standard water-soluble pigments in plants and stored in plant cell vacuoles (4). Anthocyanins have a higher antioxidant capacity than vitamins C and E (5). Besides antioxidant properties, anthocyanins also act as an anti-inflammatory (6), cardioprotective (7), anti-diabetic (8) and anti-obesity (7, 8).

The technique of extracting color from butterfly pea flowers was performed and optimized (9). The anthocyanin compounds in the extract

were also identified with five anthocyanin derivatives (10). Using natural colorants, of which blue is rare, tends to be sensitive to processing and storage conditions (11). Anthocyanin compounds are usually unstable and degrade by heat exposure during several processes such as extraction, pasteurization, sterilization and blanching (12). The stability of anthocyanins is also affected by light, pH, oxygen and enzymes (13). In addition, the extract is often in a liquid state, making it difficult to use, store and transport. To overcome the above disadvantages, the foam-mat drying method is applied, which is a process of drying liquid -solid foods by mixing with stabilizers or other foaming substances to produce stable foam before drying through a relatively low-temperature dry air ranging from 50-80 °C (14). Foam drying is one of the simpler forms compared to other methods such as spray drying and freeze-drying because it is less expensive, complicated and time-consuming (15). The foam drying method with significant advantages helps remove water when drying at low temperatures and short drying time, easily applied to products with high sugar content, high viscosity and highly sensitive compounds (15). The product obtained from drying with foam mat is better quality, porous and retains its original properties when reconstituted. This drying technique is very efficient and suitable for heat-sensitive food ingredients due to its relatively fast drying, high quality and ease of product reconstitution (16). Research on creating a color powder of butterfly pea flowers by foam drying method has not been studied yet. Studying the effect of processing on the quality of butterfly pea flower powder is interesting to create high-quality butterfly pea flower powder which meets consumers' nutritional value and sensory properties. Besides, the application in noodle processing also contributes to the diversity of products from butterfly pea flower powder, creating convenient and quick use for further processed products. Therefore, this study aimed to investigate the effect of foaming conditions on foam properties of butterfly pea flower extract, creating good conditions for the subsequent drying process. The powder quality under different drying conditions was analyzed to select the appropriate drying temperature and time for this product.

Materials and Methods

Preparation of butterfly pea flower extract

Butterfly pea flowers are grown and harvested at the College of Agriculture, Can Tho University (10°01'49.1"N 105°46'06.0"E). Flowers were collected, dried, and extracted according to the described method selected conditions (9, 17). After extraction, the extract was immediately used for the foaming process.

Effect of concentration of albumin, CMC and whipping time on characteristics of butterfly pea flower foam

The above-prepared butterfly pea flower extract (500 ml) was supplemented with albumin (6-10% w/v, 2% interval) and CMC (0.3-0.9% w/v, 0.2% interval). The mixture was then stirred at a speed of 1000 rpm (Philips HR3705/20) for 5-20 min (5 min intervals). The randomized block design with 3 replications was used. The multiple regression analysis was also applied to study the effect of foaming conditions on foam characteristics. Foam characteristics, such as foam stability and expansion, were determined to identify the optimum level of foaming conditions. After drying at 65 °C for 4 hrs, the powder was obtained and the protein content, solubility index, anthocyanin content and antioxidant activity were analyzed.

Foam stability

Foam stability was assessed by pouring 100 ml of foam into a beaker and allowing it to sit at room temperature for 3 hrs. Every 30 min, the volume reduction was measured. Equation 1 was used to calculate the foam stability (18).

$$\text{Foam stability} = V_o \times \Delta t/V_t \quad \text{(Eqn. 1)}$$

where: V_o is the initial volume of foam; $\Delta t/V_t$ is the reciprocal slope from the graph plotted between foam volume versus time.

Foam expansion

The ability of foam to cooperate with air in its structure was determined using the standard method (19) in the following Eq. 2.

$$\text{Foam expansion} = [(V_1-V_o) \times 100]/V_o \quad \text{(Eqn. 2)}$$

where: V_1 is the final volume of foam (cm^3), and V_o is the initial volume of extract (cm^3).

Quality of foam-mat dried powder

The Kjeldahl method determined the protein content using a nitrogen conversion factor of 6.38, according to method No. 988.05 (20). The anthocyanin content and antioxidant activity were determined by the pH differential method and 2,2-diphenyl-1-picrylhydrazyl (DPPH) as described in an earlier study (21). The solubility index of powder was investigated (22).

Statistical analysis

The mean comparisons were determined by using Duncan's multiple-range tests. Statgraphics centurion XV.I application was used to fitting the model to the observed data using the response surface methodology method. The effect of the independent variable on the model for response (Y) is shown in Equation 3.

$$Y = b_o + b_1A + b_2B + b_3C + b_4AB + b_5AC + b_6BC + b_7A^2 + b_8B^2 + b_9C^2 \quad \text{(Eqn. 3)}$$

Where A, B, C are independent variables, $b_{0\text{-}3}$, $b_{4\text{-}6}$, $b_{7\text{-}9}$ are offset, interaction and squared effects. The selection model was mainly based on the R^2 value obtained from the regression.

Results and Discussion

Albumin concentration, CMC concentration, and whipping time greatly influence the foam characteristics (Table 1). The advantage of foam drying is only practical when the foam's expansion is high, especially when the foam layer is mechanically and thermodynamically stable. The surface area of the dried product is increased, leading to the time required to dry the foamed product being reduced compared with the non-foam dried product (23). However,

the foam system is not stable, resulting in difficulty in drying and removing water from the drying surface (24) and led to the dried powder product having poor color, texture, taste and nutritional value (24-26).

Table 1. Effect of supplemental albumin & CMC ratio and foaming time on foam expansion and stability

X_A (%)	X_B (%)	X_C (min)	Foam expansion (%)	Foam stability (%)	X_A (%)	X_B (%)	X_C (min)	Foam expansion (%)	Foam stability (%)
6	0.3	5	307*±9.43**	83.7±0.34	8	0.7	5	437±9.43	88.8±0.65
		10	343±12.47	84.1±0.66			10	507±9.43	91.9±0.66
		15	433±12.47	87.2±0.65			15	553±4.71	96.5±0.38
		20	437±12.47	86.8±0.33			20	557±4.71	96.5±0.50
	0.5	5	337±9.43	84.3±0.38		0.9	5	427±9.43	89.5±0.47
		10	410±8.16	88.5±0.38			10	500±8.16	92.9±0.57
		15	463±12.47	94.4±0.65			15	577±12.47	95.5±0.38
		20	460±8.16	94.4±0.33			20	573±12.47	95.3±0.38
	0.7	5	323±4.71	88.5±0.38		0.3	5	447±4.71	86.9±0.38
		10	427±9.43	92.5±0.38			10	447±9.43	87.7±0.75
		15	487±9.43	96.3±0.38			15	537±12.47	91.2±0.65
		20	473±9.43	95.7±0.34			20	533±9.43	91.2±0.33
	0.9	5	307±9.43	87.7±0.41		0.5	5	447±4.71	87.5±0.38
		10	407±9.43	91.6±0.28			10	463±12.47	91.2±0.00
		15	467±9.43	94.1±0.19			15	550±8.16	93.3±0.38
		20	447±9.43	94.0±0.28			20	543±9.43	93.3±0.19
8	0.3	5	390*±8.16**	81.1±0.38	10	0.7	5	407±9.43	93.1±0.38
		10	473±4.71	87.5±0.38			10	473±12.47	94.4±0.65
		15	557±9.43	91.1±0.57			15	600±0.00	97.1±0.38
		20	543±9.43	91.2±0.33			20	590±8.16	96.7±0.19
	0.5	5	447±4.71	88.0±0.65		0.9	5	437±12.47	92.8±0.65
		10	473±9.43	91.1±0.54			10	527±9.43	92.7±0.66
		15	533±9.43	93.5±0.57			15	587±4.71	96.3±0.38
		20	523±12.47	93.6±0.33			20	567±9.43	96.1±0.09

X_A is albumin concentration (%), X_B is CMC concentration (%), and X_c is whipping time (min); Values are expressed as mean±standard deviation.

Proteins, as known as albumin, be used as stabilizers. To be a good stabilizer, it must be able to reduce the surface energy levels between the bubbles as they are continuously generated during foaming (27). With the presence of proteins in the foaming agent, when the foam is dislodged, the denatured proteins in the middle stage might interact with each other to form an elastic membrane recovery and stability, thus leading to foam formation and increased foam volume (28). The % of albumin greatly influenced foam stability and expansion. When the % of albumin increased from 6-10%, the foam stability and expansion also increased from 90.23-92.59% and 453.89-509.58%. A similar trend was observed in the foaming of egg whites and modified soy protein (29). Recent studies showed that albumins' properties contributed to an increase in foam volume and stability (27). The main requirement for successful foam drying is stable gas-liquid foam. Foaming agents include proteins, gums and different emulsifiers. A blender or a constructed instrument is used to whip mixtures into stable foams. The foam is then spread thinly as a sheet or mat and dried with a hot air stream until it reaches the correct moisture content. Drying occurs at low temperatures to create a porous honeycomb sheet or mat, which is then decomposed into a free-flowing powder (15). Proteins contribute to good foam ability and high foam stability by allowing quick adsorption at the air-water interface, creating a coherent elastic adsorbed layer (27, 28) (Table 2).

Foam stabilizers are substances that make foams less unstable. Stabilizers are usually polysaccharides. Polysaccharides do not adsorb at contact because they are hydrophilic. By thickening or gelling the aqueous solution, they have been shown to improve the stability of foam proteins (15, 27). Many researchers utilize CMC as their foam stabilizer. Foam expansion increased gradually from 453.89 to 486.11% when CMC used increased from 0.3% to 0.7% but CMC used to 0.9%, expansion tended to decrease to 485% but the no significant difference compared with the sample was used 0.7% CMC (Table 3). This decrease in foam swelling may be due to the increased liquid viscosity

Table 2. Effect of concentration of albumin on foam characteristics

Albumin concentration (%)	Foam expansion (%)	Foam stability (%)
6	407.92[a]	90.23[a]
8	504.38[b]	91.51[b]
10	509.58[c]	92.59[c]

of the foam stabilizer at higher levels. At higher concentrations, the solution becomes too viscous. The highly viscous liquid will prevent the air from being trapped during the whipping process, leading to foam expansion (25). In addition, the rate of addition of CMC is a factor that significantly affects the stability of the foam system. Surfactants help prevent bubbles' agglomeration, resulting in a longer-

Table 3. Effect of concentration of CMC on foam characteristics

CMC concentration (%)	Foam expansion (%)	Foam stability (%)
0.3	453.89[a]*	87.47[a]
0.5	470.83[b]	91.10[b]
0.7	486.11[c]	94.00[d]
0.9	485.00[c]	93.21[c]

lasting foam (30). Stabilizers have been shown to enhance the stability of foam proteins by thickening or creating the foaming effect of aqueous solutions (31). Statistical results in Table 3 also showed that when increasing the ratio of CMC from 0.3% to 0.7%, the stability of the foam system also increased from 87.47% to 94%, which shows the ability to support reducing the surface tension on the air bubbles of the CMC. The agent acts by increasing the viscosity of the continuous phase or by forming a three-dimensional lattice that slows the movement of components inside the foam (32). Foams are more stable at high viscosity because increasing the viscosity of the aqueous phase leads to the creation of a structure that will keep the network walls from breaking, improving foam stability (31).

Foaming or whipping time is one of the factors affecting the foam system. The expansion and stability of foam are presented in Table 4. During foaming time from 5 to 15 min, the swelling gradually increased from 392.50% to 528.61%, but by 20 min, there was a decrease in swelling to 520.56%. The increase in foam is due to thinner liquid film, more mechanical deformation and more bubble bursting during prolonged whipping (33). The increase in foaming time causes more modification of the albumin proteins leading to the formation of a stable foam. Similar results were reported earlier (34). The foam expansion drop due to the high whipping time may be related to the deflation caused by increasing temperature (35). Besides,

Table 4. Effect of foaming time on foam characteristics

Foaming time (min)	Foam expansion (%)	Foam stability (%)
5	392.50[a]	87.66[a]
10	454.17[b]	90.51[b]
15	528.61[d]	93.87[c]
20	520.56[c]	93.74[c]

whipping time is also one of the factors affecting foam durability. Foam stability increased from 87.66 to 93.87% when foaming time increased from 5 to 15 min; however, after 20 min whipped, stability tended to be decreased slightly. During whipping, the albumin proteins interact to form a stable, elastic interface film (35). However, after long whipping, the foam might not be stable and weak binding between compounds in foam leads to a decrease in foam expansion and stability.

Multiple regression analysis of the effect of foaming conditions on foam characteristics

Multiple regression analysis was applied to find the appropriate parameters for the foaming process, which helps the foam produced with high swelling and stability. This method successfully predicted and overlapped the multi-response to get the optimal conditions (21, 36-38). The influence of each independent variable (X_A, X_B, X_C) on the parameters (expansion and stability) of the foam is shown in Table 5. The regression model describing the relationship between the parameters of the foaming process and the independent variables (albumin ratio, CMC ratio, whipping time) was established and shown in Equations 4 & 5.

$$\text{Foam expansion (\%)} = -680.247 + 207.917X_A + 159.583X_B + 25.156X_C - 11.406X_A^2 - 112.847X_B^2 + 2.411X_BX_C - 0.697X_C^2 \quad \text{(Eqn. 4)}$$

$R^2 = 91.46$; $R^2_{adj} = 90.89$; P-value of Lack-of-fit = 0.2805

$$\text{Foam stability (\%)} = 56.64 + 1.282X_A + 47.099X_B + 1.566X_C - 0.317X_AX_B - 0.04X_AX_C - 27.622X_B^2 - 0.109X_BX_C - 0.03X_C^2 \quad \text{(Eqn. 5)}$$

$R^2 = 89.68$; $R^2_{adj} = 88.98$; p-value of Lack-of-fit = 0.1242

where X_A is albumin concentration (%), X_B is CMC concentration (%), X_c is whipping time (min)

The results show that the established equations all have high correlation coefficient R^2 (89.68 to 91.46%), greater than 80% and P value of Lack-of-fit greater than 0.05. Therefore, applying these equations to predict the change in product quality parameters with high accuracy is possible. Reports are on the determination of a good correlation between the models when the coefficient of determination of correlation (R^2) is more significant than 0.8 (39). Besides, the models were built with the Lack-of-fit test, which was not statistically significant. High compatibility between experimental data and predictive data for the parameters for foaming was also found (R^2=0.91) (Fig. 1 & 2).

Response surface was shown as contour plots showing the correlation between albumin ratio, CMC ratio, and foaming time with the foaming characteristic presented in Fig. 3 & 4. The swelling value depends on all three factors: albumin, CMC and foaming time. The swelling value reached the optimal value (587.212%) when the albumin ratio, CMC ratio and foaming time were 9.11%, 0.9% and 19.6 min respectively. In comparison, the stability reached the optimum value of 96.67% when the albumin ratio, CMC ratio and foaming time were 10%, 0.76% and 18 min respectively. It was used different concentrations of egg albumin from 5 to 20% (w/w) as a

Table 5. ANOVA of the regression coefficients for foam expansion and stability

Sources	Foam expansion (%)			Foam stability (%)		
	Mean square	F ratio	P value	Mean square	F ratio	P value
X_A	248067	1870.24	0.0000	133.482	423.28	0.0000
X_B	21233.5	160.08	0.0000	727.419	2306.72	0.0000
X_C	378583	2854.24	0.0000	840.888	2666.55	0.0000
X_A^2	66612.5	502.21	0.0000	0.28125	0.89	0.3473
X_AX_B	520.833	3.93	0.0504	1.92533	6.11	0.0152
X_AX_C	30.0	0.23	0.6355	19.3603	61.39	0.0000
X_B^2	2934.03	22.12	0.0000	175.783	557.43	0.0000
X_BX_C	1308.03	9.86	0.0022	2.69507	8.55	0.0043
X_C^2	43750.7	329.85	0.0000	80.2517	254.49	0.0000

X_A is albumin concentration (%), X_B is CMC concentration (%), X_c is whipping time (min)

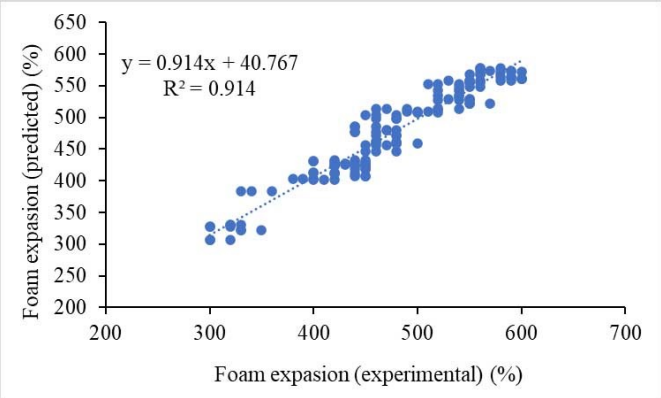

Fig. 1. Correlation between predicted and experimental foam expansion

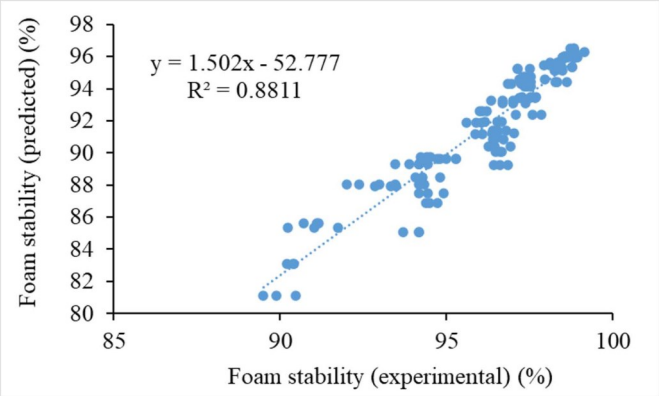

Fig. 2. Correlation between predicted and experimental foam stability

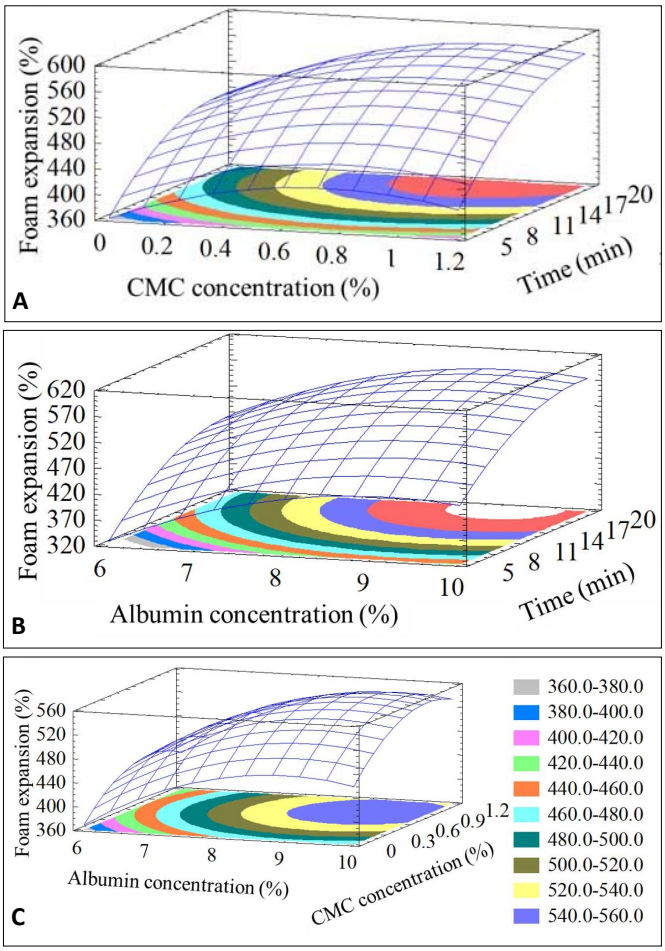

Fig. 3. Estimated response surface for foam expansion (A. Albumin concentration 8%; B. CMC concentration 0.5%; C. Whipping time 15 minutes).

foaming agent and foaming for different times (5 to 20 min) in combination with air-stable foam (40).

Since each response was optimal at different albumin ratios, CMC ratios and foaming time, the overall optimal point where all the parameters simultaneously met the requirement of high expansion and stability is visualized by overlapping contour plots (Fig. 5). The model predicted the best overall performance when using 9.3% albumin, 0.79% CMC ratio and 19 min foaming time with maximum swelling and stability of 584.79% and 96.44% respectively. Powder generated through this procedure has significant cost advantages over liquid counterparts, including lower volume or weight, less storage space, easier handling and transportation and substantially longer shelf life. Besides that, under these conditions, the protein content, anthocyanin content and antioxidant activity were 9.89 g/100 g, 1.15 mg/g and 87.34%. The solubility index of powder also was 89.45%. It could be seen that the powder has high nutritional value and antioxidant activity. In addition, foam-mat drying showed high maintenance of the antioxidant compound.

Conclusion

The foam drying method is effectively applied in drying the extract from butterfly pea flowers. Albumin and CMC supported foam stability as well as increased foam volume. The whipping process dramatically affects the foam sys-

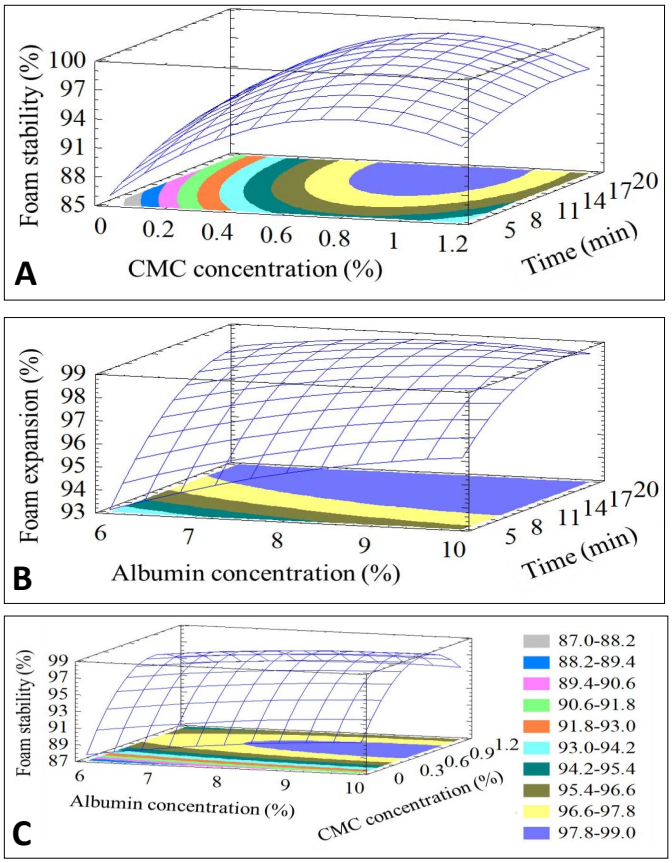

Fig. 4. Estimated response surface for foam stability (A. Albumin concentration 8%; B. CMC concentration 0.5%; C. Whipping time 15 minutes).

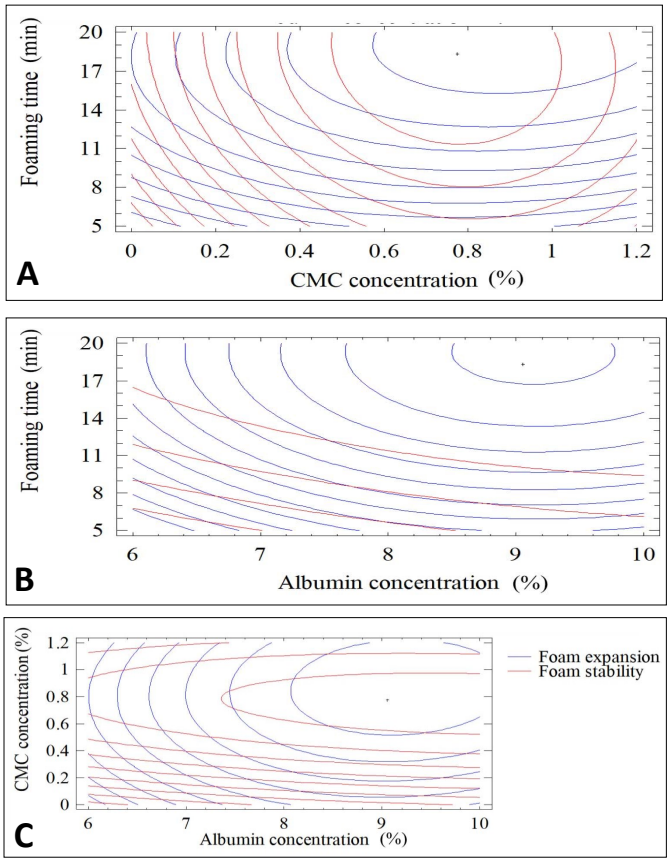

Fig. 5. Overlay plot of multi-response analysis

tem from the butterfly pea flower extract. When using the multi-dimensional regression method, the best foam properties have been found when using 0.9% albumin and 0.79% CMC and a whipping time was 19 minutes. Under these conditions, the whipped extract was dried at 65 °C for 4 hrs, giving a high nutritional and bioactive compounds content in foam-mat dried powder, which has good applicability in many commercial products. The first report about foam-mat dried butterfly pea flowers in Vietnam could be a fundamental study, which might apply on a larger scale as well as be an interesting topic for further studies.

Authors contributions

LBP carried out the experiment studies. NMT, VQM drafted the manuscript and conceived of the study and participated in its design and coordination. NVT drafted the manuscript, participated in the design of the study, performed the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

References

1. Makasana J, Dholakiya BZ, Gajbhiye NA, Raju S. Extractive determination of bioactive flavonoids from butterfly pea (*Clitoria ternatea* Linn.). Res Chem Intermed. 2017;43(2):783-99. https://doi.org/10.1007/s11164-016-2664-y
2. Sethiya NK, Nahata A, Singh PK, Mishra SH. Neuropharmacological evaluation on four traditional herbs used as nervine tonic and commonly available as Shankhpushpi in India. J Ayurveda Integr Med. 2019;10(1):25-31. https://doi.org/10.1016/j.jaim.2017.08.012
3. Daisy P, Santosh K, Rajathi M. Antihyperglycemic and antihyperlipidemic effects of *Clitoria ternatea* Linn. in alloxan-induced diabetic rats. Afr J Microbiol Res. 2009;3(5):287-91. https://doi.org/10.4314/tjpr.v8i5.48082
4. Tanaka Y, Sasaki N, Ohmiya A. Biosynthesis of plant pigments: anthocyanins, betalains and carotenoids. Plant J. 2008;54(4):733-49. https://doi.org/10.1111/j.1365-313X.2008.03447.x
5. Bagchi D, Garg A, Krohn RL, Bagchi M, Bagchi DJ, Balmoori J *et al*. Protective effects of grape seed proanthocyanidins and selected antioxidants against TPA-induced hepatic and brain lipid peroxidation and DNA fragmentation and peritoneal macrophage activation in mice. Gen Pharmacol. 1998;30(5):771-76. https://doi.org/10.1016/S0306-3623(97)00332-7
6. Duarte LJ, Chaves VC, Nascimento MVPdS, Calvete E, Li M, Ciraolo E *et al*. Molecular mechanism of action of Pelargonidin-3-O-glucoside, the main anthocyanin responsible for the anti-inflammatory effect of strawberry fruits. Food Chem. 2018;247:56-65. https://doi.org/10.1016/j.foodchem.2017.12.015
7. He J, Giusti MM. Anthocyanins: natural colorants with health-promoting properties. Annu Rev Food Sci Technol. 2010;1:163-87. https://doi.org/10.1146/annurev.food.080708.100754
8. Rojo LE, Ribnicky D, Logendra S, Poulev A, Rojas-Silva P, Kuhn P *et al*. *In vitro* and in vivo anti-diabetic effects of anthocyanins from Maqui Berry (*Aristotelia chilensis*). Food Chem. 2012;131(2):387-96. https://doi.org/10.1016/j.foodchem.2011.08.066
9. Thuy NM, Ben TC, Minh VQ, Van Tai N. Effect of extraction techniques on anthocyanin from butterfly pea flowers (*Clitoria ter-*

natea L.) cultivated in Vietnam. J App Biol Biotech. 2021;9 (6):173-80. https://doi.org/10.7324/JABB.2021.96022

10. Thuy NM, Minh VQ, Ben TC, Thi Nguyen MT, Ha HTN, Tai NV. Identification of anthocyanin compounds in butterfly pea flowers (*Clitoria ternatea* L.) by ultra performance liquid chromatography/ultraviolet coupled to mass spectrometry. Molecules. 2021;26(15):4539. https://doi.org/10.3390/molecules26154539
11. Chu B-S, Wilkin J, House M, Roleska M, Lemos A. Effect of Sucrose on Thermal and pH Stability of *Clitoria ternatea* Extract. Inter J Food Process Tech. 2016;3:11-17. https://doi.org/10.15379/2408-9826.2016.03.01.02
12. Oancea S. A Review of the Current Knowledge of Thermal Stability of Anthocyanins and Approaches to Their Stabilization to Heat. Antioxidants. 2021;10(9):1337. https://doi.org/10.3390/antiox10091337
13. Enaru B, Dreţcanu G, Pop TD, Stănilă A, Diaconeasa Z. Anthocyanins: Factors affecting their stability and degradation. Antioxidants. 2021;10(12). https://doi.org/10.3390/antiox10121967
14. Hardy Z, Jideani VA. Foam-mat drying technology: A review. Crit Rev Food Sci Nutr. 2017;57(12):2560-72. https://doi.org/10.1080/10408398.2015.1020359
15. Hardy Z, Jideani V. Foam-mat drying technology: A review. Crit Rev Food Sci Nutr. 2015;57. https://doi.org/10.1080/10408398.2015.1020359
16. Hossain MA, Mitra S, Belal M, Zzaman W. Effect of foaming agent concentration and drying temperature on biochemical properties of foam mat dried tomato powder. Food Res. 2021;5(1):291-97. https://doi.org/10.26656/fr.2017.5(1).372
17. Thuy NM, Ben TC, Ngoc PTB, Tai NV. Application of butterfly pea flower extract in processing some Vietnamese traditional foods. J App Biol Biotech. 2022;10(5):143-50. https://doi.org/10.7324/JABB.2022.100518
18. Kato A, Takahashi A, Matsudomi N, Kobayashi K. Determination of foaming properties of proteins by conductivity measurements. J Food Scie. 1983;48(1):62-65. https://doi.org/10.1111/j.1365-2621.1983.tb14788.x
19. Durian DJ. Foam mechanics at the bubble scale. Phys Rev Lett. 1995;75(26):4780-83 https://doi.org/10.1103/PhysRevLett.75.4780
20. AOAC. Official Methods of Analysis. 18th ed. Arlington, VA, USA: Association of Official Analytical Chemists, Arlington, VA, USA; 2005.
21. Thuy NM, Han DHN, Minh VQ, Van Tai N. Effect of extraction methods and temperature preservation on total anthocyanins compounds of *Peristrophe bivalvis* L. Merr leaf. J App Biol Biotech. 2022;10(2):146-53. https://doi.org/10.7324/JABB.2022.100218
22. de Paula RR, Vimercati WC, Araújo CdS, Macedo LL, Teixeira LJQ, Saraiva SH. Drying kinetics and physicochemical properties of whey dried by foam mat drying. J Food Process Preser. 2020;44 (10):e14796. https://doi.org/10.1111/jfpp.14796
23. Wilson RA, Kadam DM, Chadha S, Sharma M. Foam mat drying characteristics of mango pulp. Inter J Food Sci Nutr Eng. 2012;2 (4):63-69. https://doi.org/10.5923/j.food.20120204.03
24. Kubbutat P, Leitão L, Kulozik U. Stability of foams in vacuum drying processes. Effects of interactions between sugars, proteins and surfactants on foam stability and dried foam properties. Foods. 2021;10(8):1876. https://doi.org/10.3390/foods10081876
25. Bag SK, Srivastav PP, Mishra HN. Optimization of process parameters for foaming of Bael (*Aegle marmelos* L.) fruit pulp. Food and Biopro Tech. 2011;4(8):1450-58. https://doi.org/10.1007/s11947-009-0243-6
26. Thuy NM, Tien VQ, Van Tai N, Minh VQ. Effect of foaming conditions on foam properties and drying behavior of powder from Magenta (*Peristrophe roxburghiana*) leaves extracts. Horticulturae. 2022;8(6):546. https://doi.org/10.3390/horticulturae8060546
27. A S, Venkatachalam S, John SG, Kuppuswamy K. Foam mat drying of food materials: A review. J Food Process Preserv. 2015;39(6):3165-74. https://doi.org/10.1111/jfpp.12421
28. Manay NSO, Editor. Food: Facts and Principles 2nd edition, New Delhi: New Age International, 2001.
29. Wang G, Troendle M, Reitmeier CA, Wang T. Using modified soy protein to enhance foaming of egg white protein. J Scie Food Agri. 2012;92(10):2091-97. https://doi.org/10.1002/jsfa.5588
30. Karakashev SI, Ozdemir O, Hampton MA, Nguyen AV. Formation and stability of foams stabilized by fine particles with similar size, contact angle and different shapes. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2011;382(1):132-38. https://doi.org/10.1016/j.colsurfa.2010.09.023
31. Klitzing Rv, Müller H-J. Film stability control. Curr Opin Colloid Interface Sci. 2002;7(1-2):42-49. https://doi.org/10.1016/S1359-0294(02)00005-5
32. Walsh DJ, Russell K, FitzGerald RJ. Stabilisation of sodium caseinate hydrolysate foams. Food Res Inter. 2008;41(1):43-52. https://doi.org/10.1016/j.foodres.2007.09.003
33. Lau CK, Dickinson E. Instability and structural change in an aerated system containing egg albumen and invert sugar. Food Hydrocoll. 2005;19(1):111-21. https://doi.org/10.1016/j.foodhyd.2004.04.020
34. Raharitsifa N, Genovese DB, Ratti C. Characterization of apple juice foams for foam-mat drying prepared with egg white protein and methylcellulose. J Food Scie. 2006;71(3):E142-E51. https://doi.org/10.1111/j.1365-2621.2006.tb15627.x
35. Kandasamy P, Varadharaju N, Kalemullah S. Foam-mat drying of papaya (*Carica papaya* L.) using glycerol monostearate as foaming agent. Food Sci Qual Manag. 2012;9(1):17-27.
36. Thuy NM, Ngan HT, Tai NV. Optimization of carrot fermentation conditions in rice bran bed using *Lactobacillus plantarum*. Acta Sci Pol Technol Aliment. 2021;20(4):449-57. https://doi.org/10.17306/J.AFS.0944
37. Thuy NM, Tan HM, Van Tai N. Optimization of ingredient levels of reduced-calorie blackberry jam using response surface methodology. J Appl Biol Biotech. 2022;10(1):68-75. https://doi.org/10.7324/JABB.2021.100109
38. Van Tai N, Linh MN, Thuy NM. Optimization of extraction conditions of phytochemical compounds in “Xiem” banana peel powder using response surface methodology. J Appl Biol Biotech. 2021;9(6):56-62. https://doi.org/10.7324/JABB.2021.9607
39. Guan X, Yao H. Optimization of Viscozyme L-assisted extraction of oat bran protein using response surface methodology. Food Chem. 2008;106(1):345-51. https://doi.org/10.1016/j.foodchem.2007.05.041
40. Kandasamy P, Varadharaju N, Kalemullah S, Maladhi D. Optimization of process parameters for foam-mat drying of papaya pulp. J Food Sci Technol. 2014;51(10):2526-34. https://doi.org/10.1007/s13197-012-0812-y

§§§