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Studies on the Effect of Foaming Process Parameters on Production of Stable Tamarind (*Tamarindus indica*) Foam

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Abstract

Tamarind fruit pulp was foamed and the effect of foaming process parameters; pulp concentration (PC), foaming agent (Glycerol Mono Stearate), stabilizing agent (Xanthan), whipping time (WT) and whipping speed (WS) on foam density (FD) and foam stability in terms of drainage volume (DV) were studied using Central Composite Rotatable Design (CCRD) in Response Surface Methodology (RSM). Foam density increases with increase in the pulp concentration and xanthan quantity whereas this effect was nullified by increasing the GMS concentration. Xanthan concentration had more effect on DV as compared to GMS concentration at constant pulp concentration, whipping speed and Whipping time. While the operating conditions, whipping speed and whipping time are not having any significance influence on the drainage volume. The interaction between pulp concentration and xanthan was found to have positive effect on foam density while it had negative effect on drainage volume. The optimum conditions achieved after the numerical optimization for the minimum foam density and minimum drainage volume were Pulp concentration 7^{o} Brix, Glycerol Mono Stearate, 87.5%, Xanthan, 0.87%, whipping time, 7.71min, speed, 1600rpm. At these optimum conditions, the predicted values for foam density and drainage volume were 0.66 g cm^{-3} and 12.3 ml, respectively. The predicted values of foam density and drainage volume were 0.66 g cm^{-3} and 12.3 ml, respectively at optimum conditions while the experimental values were 0.65±0.04 g cm^{-3} and 12.67±1.15 ml, respectively.

Keywords: Central Composite Rotatable Design; Drainage Volume; Foam Density; Response Surface methodology, *Tamarindus indica*

1. Introduction

Tamarind, *Tamarindus indica* L., is a tree crop, most commonly grown in the drier warmer areas of the South and Central region of Indian sub continent. Every part of the tree is useful, but the most important is its fruit. The pulp constitutes 30-50% of the ripe fruit, the shell and fibre account for 11-30% and the seed about 25-40% (Shankaracharya, 1998). The fruit pulp is extensively used in the preparation of sambar, rasams, soups, spicy gravies, modified rice paste preparations, sweet sour sauce etc. as an important ingredient for its sweety-sour taste. With the increasing use of tamarind in food preparations, ready-to-use tamarind powder has found a market place. However the production of powder from the pulp is practically not possible using tray drying since it contains major percentage of simple sugar leads to its viscous nature. Foam- mat drying is an advanced version of tray drying in which the food is made into foam thereby the surface area of the food product is increased, facilitating the quick and easy removal of moisture from the food. This technique is a promising new development in the field of drying aqueous foods, which are heat sensitive and difficult-to-dry, sticky, and viscous under relatively mild conditions without undue quality change (Kadam *et al.* 2010).

Foam-mat drying techniques have been used to dry fruits like orange and apple using GMS, methocel, egg albumin and also to dry cow pea (Labelle, 1966; Falade et al. 2003; Raharitsifa et al. 2006). However Success of foam mat drying depends on the production of stable foam and is affected by many factors such as pulp concentration, concentration of foaming and stabilizing agent, whipping time and whipping speed (Bag et al., 2009).In this context, the present study was carried out at Department of Food Process Engineering, SRM University, Chennai during 2009-2013 to cater to fulfill the following objectives (a)To study the effect of process parameters on the production of stable foam (b)To optimize the process parameter for the production of stable foam.

2. Materials and Methods

2.1 Tamarind pulp and foaming additives

The PKM variety of tamarind fruit used in the study were procured from Horticulture College and Research Institute, Periyakulam, Tamil Nadu, India. The foaming additives, Glycerol Mono Stearate and Methyl Cellulose (hereafter mentioned as GMS and MC, respectively) used in the study were of food grade chemicals procured from Sigma Aldrich Chemicals, Mumbai. Tamarind fruit without seed was mixed with three parts of water to get tamarind paste of 18 ^{o}Brix. The extracted pulp was strained through 25 mesh stainless steel sieve. 100 ml of tamarind paste of 18 ^{o}Brix was mixed with 12ml, 10ml, 8ml, 6ml and 4ml water to get tamarind pulp of 7-15 ^{o}Brix concentration. The concentration of prepared pulp was checked with the refractometer (ERMA, Japan). A suspension of GMS was prepared by slightly modifying the method of Oguntunde and Adeojo (1992).

2.2 Experimental Design and Data Analysis

Experimental design consisting of 53 runs, of which 32 were factorial, 10 were axial and 11 were at centre point (Montgomery, 2001) was obtained from Central Composite Rotatable Design (CCRD) in Response Surface Methodology (RSM) using the statistical package (Design Expert 2008, version 8.0.7.1 STAT-Ease, Inc, MN, USA) was used to conduct the experiments. The full second order model represented by Eq. 1 was fitted to the data for all the responses, regression analysis and analysis of variance (ANOVA) were conducted for the experimental data by fitting them into the model. The statistical significance of the model terms were examined by computing the F value at 5%, 1% and 0.1% level (Table 1).

$$y = \beta_0 + \sum_{i=1}^{5} \beta_i X_i + \sum_{i=1}^{5} \beta_{ii} X_{ii}^2 + \sum_{i=1}^{4} \sum_{j=i+1}^{5} \beta_{ij} X_i X_j \quad (1)$$

Where, $\beta_0, \beta_i, \beta_{ii}, \beta_{ij}$ are Regression coefficients; $X_i X_j$ are independent variables; Y is dependent variable

The adequacy of the model was determined using the model analysis, Lack of Fit test and R^2 (co-efficient of determination) analysis. Response surfaces and contour plots were generated using Design Expert. 8.0. to study the effect of process parameters on foam quality.

2.3 Foaming Trails and Foam Quality Evaluation

Foaming trails were performed for all the 53 experiments. Foam density of the prepared foam was determined by the method described by Karim and Wai (1999) with slight modification. Foam stability was measured in terms of drainage volume, method described by Sauter and Montoure (1972) and Narender and Pal (2009) with slight modification.

2.4 Optimization and Model Validation

Numerical optimization was carried out by setting numerical constraints for the independent variables to obtain the foam with minimum foam density (FD) and drainage volume (DV). Predictive models were used to graphically represent the system. To ascertain the accuracy of the optimized process parameters obtained for the prediction of foam density and drainage volume, experiments were conducted using optimized process parameters in triplicate.

3. Results and Discussion

3.1 Effect of Process Parameters on Foam Density

The foam density was calculated for the 53 experiments and it varied between 0.51 and 0.95g cm-3.Further from the analysis of variance (Table 1) it is clear that foam density was seemed to be highly significant ($P<0.1\%$) with respect to PC and Xanthan in terms of linearity. While the linear terms of GMS concentration was found to have no significant effect on foam density, the quadratic terms of GMS concentration is found to be highly significant at 0.1% level,. With respect to interactive terms, the interaction between pulp concentration and xanthan affects the foam density significantly at 5% level. Further, non significant terms were removed from Eq. 1 to obtain quadratic prediction equation (Eq. 2) using the Design Expert Version. 8, which is clearly demonstrated the influence of process variables on foam density of produced foam.

$$FD = 0.697+0.060X_1+0.048X_3- 0.021X_2^2 -0.017X_1 X_3 \ ((R^2=0.87) \qquad (2)$$

Where X_1 is the pulp concentration (^{o}Brix), X_2 is GMS concentration (%w/v) and X_3 is xanthan concentration (%w/v).

With regard to first order terms, the pulp concentration and the xanthan quantity are positively correlated with the foam density which was evidenced by consistent increase in foam density with an increase in the pulp concentration and xanthan quantity. The quadratic terms of GMS concentration and the interaction between pulp concentration and xanthan are negatively correlated with the foam density which is a positive result in this study, further indicates that, more amounts of GMS is needed to be mixed with the tamarind pulp to nullify the effect of xanthan and pulp concentration on foam density. Similar trends were reported for cowpea (Falade et al. 2003) and banana (Sankat and Castaigne, 2004).

3.2 Effect of Process Parameters on Drainage Volume

In the present study drainage volume varies from 5 to 60 mL and affected significantly due to the interaction between pulp concentration and xanthan as well as GMS concentration and Xanthan at 5% level. While the linear terms of pulp concentration and the quadratic terms of GMS concentration were significant at 5% level, the linear terms of xanthan was significant at 0.01% level. The non significant terms of regression equation (Eq.1) were removed with the view to get the improved model. By this, a reduced quadratic model (Eq. 3) was obtained, which describes the effect of process variables on the drainage of the produced foam.

$$DV= 21.167-3.735X_1-12.629X_3+2.051X_2^2+4.188X_1 X_3+4 X_2 X_3 \ (R^2=0.87) \qquad (3)$$

Where X_1 is pulp concentration (^{o}brix), X_2 is GMS concentration (%w/v) and X_3 is xanthan concentration (%w/v).

Eq.3 reveals the negative correlation between pulp concentrations, stabilizer quantity on drainage volume which is a positive phenomenon. On the other hand, quadratic terms of GMS concentration, interactive terms of pulp concentration and xanthan concentration; GMS and xanthan concentration are positively correlated with drainage volume, indicating that drainage volume increases with the increase of these variables.

Table 1: ANOVA results of responses with their estimated process factors coefficient

Factor	Foam density			Drainage volume		
	Coefficient of estimate	F value	Prob>F	Coefficient of estimate	F value	Prob>F
β_0	0.697***	9.239	< 0.0001	21.167***	9.108	< 0.0001
β_1	0.060***	92.529	< 0.0001	-3.735*	11.367	0.0022
β_2	-0.010	2.643	0.1152	-1.465	1.749	0.1967
β_3	0.048***	58.798	< 0.0001	-12.629***	129.959	< 0.0001
β_4	0.002	0.059	0.8095	-0.905	0.667	0.4210
β_5	-0.008	1.786	0.1921	0.144	0.017	0.8979
β_{11}	-0.002	0.175	0.6785	0.460	0.238	0.6297
β_{22}	-0.021***	15.899	0.0004	2.051*	4.718	0.0385
β_{33}	0.006	1.192	0.2843	1.786	3.577	0.0690
β_{44}	-0.003	0.269	0.6079	1.609	2.904	0.0994
β_{55}	0.004	0.447	0.5090	0.460	0.238	0.6297
β_{12}	-0.005	0.390	0.5372	1.188	0.849	0.3647
β_{13}	-0.017*	5.269	0.0294	4.188*	10.555	0.0030
β_{14}	0.002	0.092	0.7645	0.500	0.150	0.7010
β_{15}	-0.002	0.086	0.7710	0.500	0.150	0.7010
β_{23}	-0.011	2.365	0.1353	4.000*	9.631	0.0043
β_{24}	-0.002	0.095	0.7600	-0.438	0.115	0.7368
β_{25}	-0.002	0.096	0.7594	0.938	0.529	0.4730
β_{34}	-0.008	1.193	0.2841	2.063	2.561	0.1208
β_{35}	0.006	0.631	0.4336	-2.563	3.953	0.0567
β_{45}	0.001	0.011	0.9173	-0.125	0.009	0.9234

*Significant at 0.05 level **Significant at 0.01 level ***Significant at 0.001 level.

3.3 Optimization of foaming process parameters

The optimum foaming conditions to get minimum foam density and minimum drainage volume obtained using numerical optimization and desirability function method were Pulp concentration 7^o Brix, Glycerol Mono Stearate, 87.5%, Xanthan, 0.87%, whipping time, 7.71min, speed level, 5. At these optimum conditions, the predicted values for foam density and drainage volume were 0.66 g cm^{-3} and 12.3 ml, respectively. The experimentally determined values of foam density and drainage volume at these optimum conditions were 0.65±0.04 g cm^{-3} and 12.67±1.15 ml, respectively. This indicates the suitability of the developed equation in predicting the foam quality.

4. Conclusion

GMS +X was found to be suitable for the production of stable foam. The optimum foaming conditions to get minimum foam density and minimum drainage volume were

Pulp concentration 7^{o} Brix, Glycerol Mono Stearate, 87.5%, Xanthan, 0.87%, whipping time, 7.71min, speed, 1600rpm. At these optimum conditions, the predicted values for foam density and drainage volume were 0.57 g cm^{-3} and 14 ml, respectively The experimentally determined values of foam density and drainage volume at these optimum conditions were 0.65±0.04 g cm^{-3} and 12.67±1.15 ml, respectively.

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