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Analysis of Foaming Properties of Mango Pulp for Foam-mat Drying: Impact of Egg Albumin Concentration and Whipping Time

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Abstract - Recently, foam-mat drying becoming an essential technology for drying fruits and vegetables because simple, cost-effective, rapid drying, suitable for drying viscous materials, retaining the food values, and less thermal degradation. The functional features of this drying, such as foam expansion, stability and density, are playing a significant role in improving moisture transfer rate and product quality. In this study, the influence of egg albumin concentration and whipping time on the foaming properties of mango pulp was investigated. The egg albumin concentrations of 5, 10, 15 and 20% were added with mango pulp and then whipped using a hand blender at maximum speed. The foaming properties were tested at whipping time intervals of 5, 10 and 15 min. The results showed that the volume of foam increased significantly, whereas decreased foam density with increasing the concentrations of egg albumin. The maximum foam expansion of 104.6%, minimum foam density of 0.447 g/cm³ and highest foam stability of 91.87% was obtained at 15% egg albumin concentration at a whipping time of 15 min. The foam received in this condition was stable up to 210 min.

Keywords - Mango fruit; egg albumin; whipping; foam expansion; foam stability; foam density

INTRODUCTION

Mango (*Mangifera indica* L.) is an important economic crop and has a rich source of carotenoids, flavonoids, vitamins, minerals, and dietary fibre. As the shelf life of mango is minimal, the marketing of fresh fruits is a significant problem that leads to high postharvest losses [1]. Therefore, the production of value-added products is the only way to prevent postharvest losses. The dehydrated mango powder can be used for the preparation of many food product formulations [2]. Foam-mat drying is an effective technique for drying liquid, semi-liquid, heat-sensitive, sticky, viscous, and sugar-rich food materials and reduces drying time. When converted to stable foams, they can be dried rapidly under heated air to yield instant powders. This method transforms liquid food concentrate into a stable foam through whipping and an appropriate edible foaming agent. It is subjected to dehydration at a relatively low temperature in the form of a foam mat [3-6].

The major functional characteristics of foam-mat drying are foaming power or expansion, foam stability and foam density. Foam expansion indicates the amount of air entrapped into the fruit pulp during whipping. It can be determined by measuring an increase in foam volume upon introducing a foaming agent and gas into protein solution after whipping. Foam stability denotes the rate at which liquid drains from the foam, and it can be determined by measuring the rate of liquid discharge from foam or the rate of decrease in foam volume with time. The drainage of liquid is accompanied by thinning of the foam, which enhances the probability of film collapse leads to increase drying time [7-8].

Foam density can be measured by its ratio of weight and expansion volume of foam [9-10]. Different factors such as type of foaming agents and their concentrations, chemical nature and concentration, viscosity, sticky, sugar content, fibre content, whipping time, operating parameters of foaming device, and temperature mainly influence the foaming properties [10-12]. The food emulsifiers include methylcellulose, carboxyl methylcellulose, egg albumin, glycerol monostearate, guar gum, soy protein, sorbitan-mono-stearate, sucrose monolaurate, sucrose monopalmitate and tapioca starch are mainly used as foaming agents [13].

Foam structure plays a significant role in moisture movement during drying and also in subsequent product quality. If there is no rupture in foams for at least 1.0 h, it is considered thermally stable for the entire drying process. Thermally stable foams retain their porous structure, which aids improvement in the reconstitution properties of the foam mat dried product. The unstable foamed products are difficult to dry and have poor colour, texture, flavour, and nutritional value [7,10,11]. The addition of foaming and stabilizing agents helps in increasing foam stability during drying. The foam obtained with low dosed stabilizer agent is unstable, whereas overdosed stabilizer can result in foam rupture. The concentration of the foam stabilizer should be optimized as below the critical concentration, the foam is inconsistent [14]. The study was aimed to analyze the effect of concentration of egg albumin and whipping time on foaming properties such as foam expansion, stability and density of mango pulp.

MATERIAL AND METHODS

Raw materials

The ripened mango fruits were procured from the local farmer's field, washed in water, and kept in the laboratory at atmospheric condition until they attained the desired peel colour. The fruits were peeled manually using stainless steel knife, and flesh portions were homogenized using a food processor (Icon Superb 1000W, Morphy Richards, Mumbai, India). The pulp was packed in a sterilized stainless steel container and heated in boiling water for 15 min to inhibit microbial and enzymatic activity. Egg albumin was used as a foaming agent and stabilizer since it stabilizes the foam longer [15]. This study purchased fresh eggs from the local market and separated the albumin using a yolk separator (Rrimin, Chennai, India).

Foaming studies

The foaming experiments were designed with four levels of egg albumin (5, 10, 15, 20%) and three levels of whipping time (5, 10 and 15 min) as independent variables and foaming properties such as foam density, foam expansion and foam stability as dependent variables to optimize the level of foaming agents. About 200 mL of homogenized mango pulp was taken in a graduated transparent fibreglass container, and a selected level of egg albumin was incorporated on a w/w basis. Whipping was done using an electric beater (Philips HR-3705/10 300 W Hand Mixer) with maximum speed to obtain consistent foam. A reliable foam can be expressed in maximum foam expansion with minimum density and stable long time for drying. The initial volume of pulp before whipping and the final volume of foamed pulp after beating were measured with the help of a graduated scale provided inside the container. The foaming behaviour was determined by employing foam expansion, foam stability and foam density.

Determination of foam expansion

Foam expansion indicates the amount of air entrapped into the fruit pulp during whipping along with the foaming agent. Foam expansion was calculated by the difference in the volume of fruit pulp before whipping and volume of foamed pulp after whipping and expressed in per cent [3]:

$$EF = \frac{V_f - V_p}{V_p} \times 100$$

where EF is the foam expansion (%), V_p is the initial volume of mango pulp (cm^3), and V_f is the final volume of foamed mango pulp (cm^3).

Determination of foam density

The mango foam of about 50 ml was transferred into a graduated measuring cylinder. It was ensured that no trapping of air voids and collapsing of the foam structure. The weight and volume of foam were measured, and foam density was calculated using the following relationship [4]:

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$$FD = \frac{W_f}{V_f}$$

where FD is the foam density (g/cm^3), W_f is the weight of foam (g), and V_f is the volume of foam (cm^3).

Determination of foam stability

For drying of foam in a short time, the foam should be stable for a long time with minimum drainage volume. About 100 mL of foamed mango pulp was taken in a transparent graduated beaker and kept at room temperature for 3 h. The volume of liquid juice separated from the foam due to drainage. The reduction in foam volume was measured as an index for the foam stability for every 30 min. The stability of foam was calculated using the following relationship [16]:

$$FS = \frac{\Delta V_{ft}}{V_{0f}} \times 100$$

where ΔV_{ft} is the foam volume as the difference between the initial foam volume and the dripped liquid (ml) volume, and V_{0f} is the initial foam volume (ml).

Statistical analysis

Triplicate determinations were made on each treatment, and mean values were computed. The results were statistically analysed by completely randomized design using the SPSS software (version 16.0.0 software, SPSS Inc., Chicago, USA) and defined the significance at a 5% level.

RESULTS AND DISCUSSION

Effect of whipping time on foam expansion

Whipping is the most fundamental parameter in the development of food foam, and the volume of foam increases as a function of whipping time. The amount of air introduced into liquid or semi-liquid foods containing a foaming agent is entrapped by the interfacial film to become foam due to whipping. The volume of foam increased as the whipping process continued. Foam volume gradually increased up to 10 min whipping time after that, not much increase in foam volume (Fig. 1). Development of numerous air bubbles, increasing the size of air bubbles, subsequently breaking into tiny bubbles and collapsing the air bubbles due to the mechanical agitation and rheological properties of the liquid may be the causes for increasing and decreasing foam volume during whipping [15,17]. Whipping involved in rigorous mechanical stress affects both coalescence and the formation of bubbles. Higher whip ability can entrap more air within the liquid, on the other hand, collapse the air bubbles when it exceeds [10,18].

Effect of egg albumin concentration on foam expansion

Fig. 1 shows the effect of levels of egg albumin and time of whipping on foam expansion. The results showed that the foam volume increased while increasing the concentration of egg albumin from 5% to 20%. The foam expansion of 23.66%, 62.67%, 104.60% and 110.65% was recorded at 5, 10, 15 and 20% egg albumin, respectively, at a whipping time of 15 mm. No significant increase in foam overrun by adding egg albumin beyond 15%; instead, a reduction in foam volume was observed. The air bubbles were not stable at lower concentrations of egg albumin due to the interfacial film could not being formed. The increase in foam volume is due to the formation of a solid interfacial film by denaturalizing the protein molecules of the egg albumin during whipping, stability of the interfacial film, reduction of surface tension and interfacial tension aqueous system [7]. The interfacial film's ability to entrap and retain more air volume leads to the expansion of foam [17]. The decrease in foam volume may be due to mechanical stress on the foam bubbles leads collapsing of the bubbles [19].

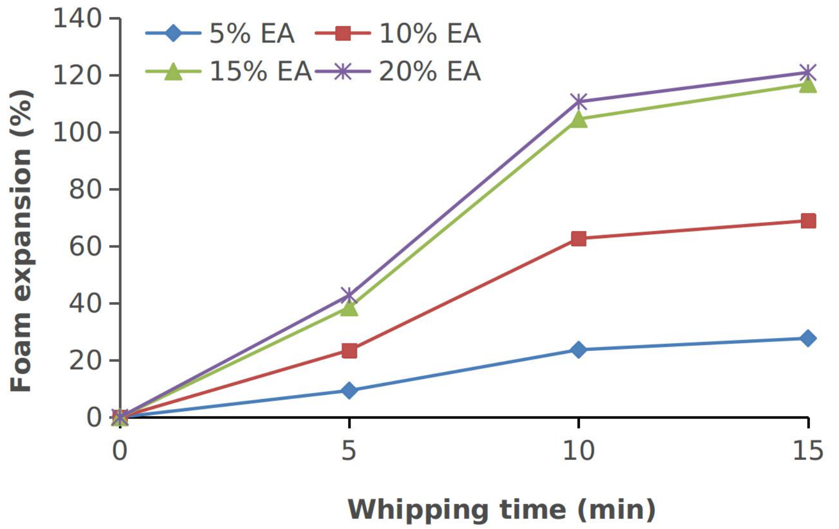

Fig. 1 Effect of whipping time and concentration of egg albumin on foam expansion.

Effect of egg albumin concentration on foam density

The effect of whipping time and concentration of egg albumin on foam density is presented in Fig. 2. The results showed that the foam density decreased significantly with increasing the level of egg albumin. The foam density of 0.759, 0.574, 0.447 and 0.438 g/cm^3 was observed at 5, 10, 15 and 20% egg albumin, respectively, at a whipping time of 15th min. Besides increasing the level of egg albumin beyond 15%, no significant reduction in foam density. At this stage, the mango foam density lies in the broad range of 0.2-0.6 g/cm^3. A decreasing trend in foam density was observed with increasing concentration of foaming agent and increasing the concentration of foaming agent beyond this levels; no appreciate a reduction in the foam density. The lower foam density while the increasing foaming agent concentration may be due to more air entrapped in the mango pulp during the whipping process. The lower foam density at a higher level of egg albumin due to enormous air trapped in the mango pulp during whipping reduces the liquid's interfacial tension and surface tension to form an interfacial film that exceeds the critical thickness [7]. Similar trends were observed for cowpea [18], bael pulp [10] and pineapple fruit [16].

The higher foam density at a lower concentration of foaming agents limits the diffusion of a foaming agent from the aqueous phase to the air-aqueous interface. Thus, the air bubbles are not stable [6]. Apparently, at a lower concentration of the foaming agent, the air bubbles were not stable because the critical thickness required for the interfacial film could not be formed [7]. The low-density foams are stabled for a longer time, thereby reducing drying time, and the optimum range of density of foamed material is ranged between 0.2 and 0.6 g/cm^3 [14]. The foams with higher density resulted in prolonged drying time, leading to inferior powder quality due to thermal degradation [20]. Whipping time significantly influenced the mango foam density. Foam volume increased over the whipping time due to the incorporation of enormous air bubbles in the foam during whipping leads to decrease foam density, increased surface area of the foam and faster evaporation rate during drying [4]. The excessive whipping (overbeating) leads to increase foam density due to foam collapse [9]. The high degree of aeration, thinning of the liquid film between the foam bubbles and mechanical deformation led to rupturing the foam bubbles [18].

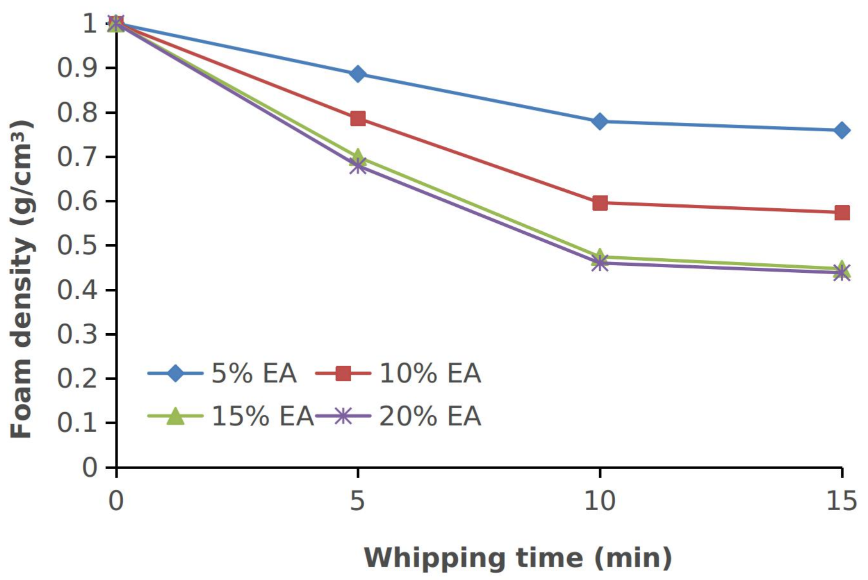

Fig. 2 Effect of whipping time and concentration of egg albumin on foam density.

Effect of concentration of foaming agents on foam stability

The foam obtained from a whipping time of 15 min was taken for stability analysis because high foam expansion and low-density foams were achieved in this condition. The trials were conducted for up to 210 min as the foams tend to collapse and drain over time. The foam stability decreased overtime at all the foaming conditions (Fig. 3). Foam obtained with 15 and 20% egg albumin exhibited more stability than foam obtained with 5 and 10% egg albumin. The stability of foams at 5, 10, 15, and 20% egg albumin were 84.76, 88.56, 91.87 and 92.83%, respectively, at the end of 210 min.

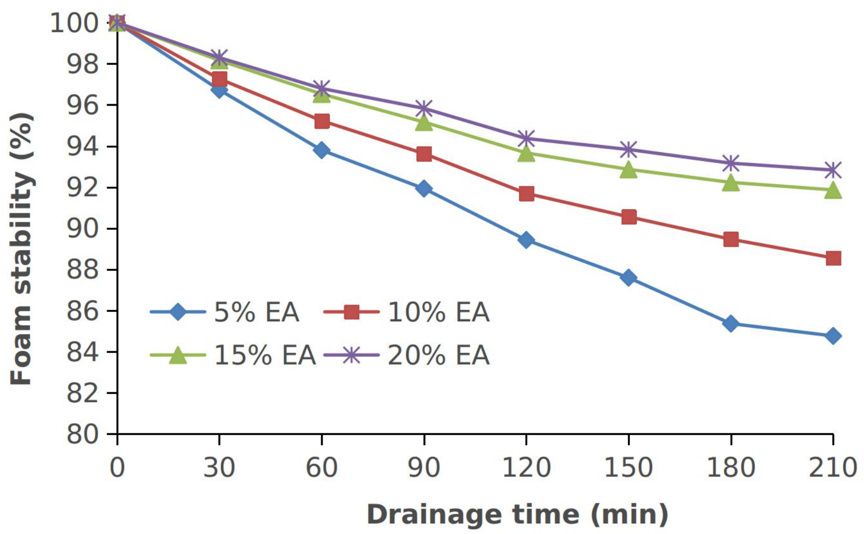

Fig. 3 Effect of whipping time and concentration of egg albumin on foam stability.

This higher foam stability may be due to an increase in the strength of interfacial visco-elasticity film of foam lamella at a higher level of egg albumin protein, and the hydrophobic nature of hydrocolloids prevents the plateau borders against collapse. This may be the reason for higher foam stability at a higher level of egg albumin. The stable foam structure is desirable for rapid drying and ease of removing the dried material from the tray. If foams are getting a break or drain excessively, drying time will be increased and reduce the product quality. Foam stability depends on the thickness of the interface, foam size distribution, interface permeability, and surface tension [21]. Similar results, the effect of concentration of foaming agents on foam stability were reported for apple juice [9], bael pulp [10] and cowpea [18].

Foam stability reflects the water holding capacity of the foam and is one way to determine the rate of liquid drains from it [8]. The liquid in foams is distributed between thin films and plateau borders. The pressure inside the bubble is less than the outside of the thin films due to capillary force. This difference, known as plateau border suction, leads to liquid drainage from thin films to the neighbouring plateau border. Finally, liquid in the plateau border of foams is subject to the drain of the liquid from between the bubbles caused by the action of gravity. The hydrophobic nature of stabilizers also strengthens the bubble walls, thus, in turn, stabilizing the foam structure from collapsing [15,17].

CONCLUSION

Foaming properties are the most critical factors in the foam-mat drying of food materials. The drying time, drying rate, and product quality depend on the foam properties. This study investigated the effect of different concentrations of egg albumin and whipping time on foaming properties such as foam expansion, foam stability, and foam density of mango pulp. As the concentration of egg albumin increased, the foaming power and stability increased significantly; however, foam density decreased. The foam volume gradually increased up to 10 min whipping time after that no much increase in foam volume. The maximum foam expansion of 104.6%, minimum foam density of 0.447 g/cm^3 and highest foam stability of 91.87% was obtained at 15% egg albumin concentration at a whipping time of 15 min. The foam received in this condition was stable up to 210 min.

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