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Review Article

FOAM MAT DRYING OF HIGH VALUE FOODS

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Abstract: Foam mat drying is a process by which a liquid or semi-liquid is whipped to form a stable foam and subsequently dehydrated by thermal means. Foams are spread on a tray, which is then air dried at low temperatures. In this method of drying a liquid food concentrate along with a suitable foaming agent is whipped to form a stable foam and is subjected to dehydration in the form of a thin layer of foam at relatively low temperature. This technique is used for foods which are highly heat sensitive and very sticky to dry. Different foaming agents (egg albumin, soy protein, egg white, Lecithin) and foam stabilizers (carboxymethyl cellulose, pectin) used to do mixed in different concentration in the fruit and vegetable pastes to introduce stable foams. Hot air is used to dry foams in trays then mill them into free-flowing powders.

Keywords: *Foam-Mat Drying, Foaming Agent, Stabilizer*

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Introduction

Fruits and vegetables are agricultural crops that are grown in excess during their season. Fruits and vegetables have a limited shelf life after harvesting. They are subjected to microbial and enzymatic spoilage after a few days, resulting in off flavour and colour. Because of improper processing and storage, a large portion of fruits and vegetables are wasted.

All fruits and vegetables are highly perishable and have a higher water content. The primary environment for bacterial growth and reproduction is water. Food contains water, which participates in a variety of chemical processes like oxidation and non-enzymatic browning. Water availability is also a factor in enzymatic and microbial activity. Therefore, we can reduce or eliminate the water content in our foods to prevent the growth of various organisms that lead to food spoilage.

Drying is the primary method for preserving various fruits and vegetables. Fruits and vegetables are dried using heat, which reduces the water content of the fruits and vegetables, inhibits the growth of various enzymes and microbes, and increases product stability. Furthermore, drying reduces product volume, which lowers the cost of packaging, transportation, and storage. Drying methods include direct sun drying, solar augmented drying, freeze drying, microwave drying, hoover drying and infrared drying. The selection of a suitable drying method is essential in terms of cost and final product quality. Some of these drying methods require large instalments and have high energy costs, making them unsuitable. Many compounds found in fruits and vegetables are extremely sensitive.

Another promising technique for obtaining dehydrated foodstuffs aimed at retaining the bioactive compounds and natural characteristics is foam mat drying (FMD). In this technique, liquid-solid foods that have been mixed with a stabilising agent or a foaming agent to produce stable foam.

Foam-mat drying

Foam mat drying is a gentle drying method for semiliquid and liquid foods. It is beneficial for heat-sensitive and sticky liquid foods. Using surfactant additives, such as a foaming agent or a foam stabiliser, liquid food is converted into foam by whipping. Foams are spread on a tray, which is then air dried at temperatures ranging from 40 to 80 °C, and the dried product is scraped, ground, and sieved to obtain powders [1].

Several another methods can also be used for drying such as vacuum, microwave, and freeze-drying. Less time is required for drying the foam because the larger surface area exposed to the drying air which accelerates the moisture removal process. The drying time required for foamed pulp used to be lower than non-foamed pulp [2].

Fruit and vegetable paste or juice
↓
Addition of foaming agent and foam stabilizer
↓
Whipping to produce foam
↓
Spread on trays in thin layer and dry in dryer
↓
Scraping from trays and ground in fine powder
↓
Packaging

Fig-1 Process Flow chart of foam mat drying

Foaming agents

Surface-active agents used in this technique, namely foam stabilizer and foaming agents. These agents can be broadly classified into two classes: Carbohydrates (xanthan gum, gum arabics, maltodextrin, methyl cellulose) and proteins (egg albumins, pea protein isolate, whey protein isolate, soy protein isolate)

Applications of foam-mat drying

The method described here is appropriate for heat-sensitive, viscous, and sticky products that, due to their state, cannot be dried using other drying methods for example spray drying. Because of its easy use, rapid drying, and enhanced quality of the goods, foam-mat drying has gained popularity. Because of its efficacy for all types of juices, rapid drying at lower temperatures, nutritional quality retention, easy reconstitution, and cost-effectiveness for producing easily reconstitute juice powders, this process can be used for large-scale production of fruit powders.

When compared to freezing and spray drying, foam mat powders can be easily reconstituted [3]. Fruit-based powders obtained through this method have significant economic advantages over liquid counterparts, including lower volume or weight, less storage space, easier handling and transportation, and a much longer shelf life. The advantage of foam-mat drying is that it shortens the drying time, which reduces harmful effect of heat and prevents the degradation of heat-sensitive compounds in foods. A short drying time can also help to prevent changes in the physical properties of the foods. Thus, high drying rate during foam-mat drying and lower drying temperatures makes this process economical as compared to other drying methods [4].

Drying of fruits and vegetable using foam-mat drying

Bag *et al*., (2011) [5] studied the foam-mat drying of bael fruit. Foams were prepared from various pulp concentrations (PC) by adding different concentration of glycerol monostearate (GMS) and methyl cellulose (MC) at different whipping time. The optimum conditions achieved after the numerical and graphical optimization for maximum foam expansion and stability was: GMS (3.10 g/100 g pulp), MC (0.32 g/100 g pulp), PC (13.2°Brix), and WT (2 min). The stability of foam is influenced by the thickness, permeability of the shared surface of air-liquid, bubble size distribution and adhesion. Kandasamy *et al*., (2014) prepared papaya powder using foam-mat drying method. They used methyl cellulose, glycerol-mono-stearate, and egg white as foaming agents. They used batch type cabinet dryer for foam drying using air temperature of 60, 65 and 70 °C with foam thickness of 2, 4, 6, 8 and 10 mm. The maximum stable foam formation was 72, 90 and 12.5% at 0.75 % methyl cellulose, 3 % glycerol-mono-stearate and 15 % egg white respectively with 9°Brix pulp and whipping time of 20 min.

Khamjae *et al*., (2018) [6] investigated foam-mat drying of passion fruit aril. They observed that how methylcellulose concentration and whipping time affect the properties of passion fruit aril foam. The low-density, highly stable passion fruit aril foam would be produced by adding 2.25% methylcellulose with a whipping time of 25 minutes. The drying foam-mat process of passion fruit aril significantly reduced microbial load, and the dried product obtained was deemed safe. Drying took place mostly during the falling rate period, with lower drying rates occurring at lower drying temperatures and thicker foam. The highest foam expansion (187.25%) and stability, as well as the lowest foam density, were obtained with 2.25% methylcellulose after 25 minutes of whipping.

Osama *et al*., (2022) [7] found the effect of foam thickness, drying temperature, foaming agent ovalbumin concentration and water dilution on foam mat drying of kadam fruit pulp. They observed that on increasing the foam thickness and the drying temperature drying rate increased. They also found the significance of adding water during foam mat drying. Foaming is difficult in some fruits because the pulp lacks cohesiveness. The addition of water causes foam to form, which increases drying rates and moisture diffusivity. Furthermore, the uniform temperature distribution in foam mat drying produces high-quality fruit powder. The overall colour change decreased slightly and then increased as the foam thickness increased. Pasban *et al*., (2022) [8] analysed foaming properties of white button mushroom (*Agaricus bisporus*) by response surface methodology. For optimization, xanthan gum (XG) solution range was considered between 0.05 –0.3% w/w, mushroom concentration (water: mushroom puree) range was considered 1:0.5 – 1:3.5 w/w and whipping time range was taken between 2 –8 min. The influence of the drying temperatures on some qualitative attributes of foam – mat dried mushroom powder was investigated. They found that, as the temperature increased, water binding capacity decreased.

Effect of foaming agent, concentration of product, whipping time on drying

Foam properties including density, expansion ability and stability significantly affected by the interaction of foaming agent concentration and whipping time. Usually, Density is used to evaluate the whipping properties. Falade *et al*. (2003) [9] during their experiment on cowpea found that at any given methylcellulose concentration, an increment of whipping time resulted in a reduction of foam density. In addition, the foam expansion increased with increasing whipping time. Foam volume (i.e., foam expansion) and foam density are commonly used to evaluate whipping properties. During the whipping process, air bubbles were trapped in the foam and gave rise to lower foam density. Therefore, the more air incorporated during whipping, the lower the foam density; the more air present in the foam, the greater the foam expansion. Abbasi *et al*., (2015) [10] evaluated physicochemical properties of sour cherry powder produced by foam mats drying method. The egg white and methyl cellulose, were used as foaming agent and foam stabilizer, respectively. As the level of methylcellulose increased, drainage volume, foam density, browning index and drying time were reduced; however, solubility and pH of the samples had an increasing trend. By the increase of drying temperature, total acidity increased. Durge *et al*., (2015) [11] carried out foaming of sapota pulp by foaming device at various levels of pectin, egg albumin and methyl cellulose at different levels. The influences of pectin, egg albumin and methyl cellulose concentration on the foaming characteristics in terms of foam expansion and foam stability were subsequently evaluated. Higher concentration of foaming agents within selected range produced uniform size of air bubbles. It was observed that pectin gives more (double) volume of foam compared to that produced using egg albumin.

Watharkar *et al*., (2021) [12] investigated the foam-mat drying characteristics of wild ripe banana pulp on the attributes of the product. Water activity, moisture content, bulk density, and Carr index of banana foam powder decreased as drying temperature increased, whereas hygroscopicity, water solubility index, and water absorption index increased. The dried samples were moderately bright in color and had a porous microstructure. Mahmut *et al*., (2023) [13] produced tomato powder from tomato puree with foam-mat drying using green pea aquafaba. The drying parameters and bio accessibility of bioactive compounds also observed. The main aim of this study was to valorize green pea cooking water (aquafaba) as a foaming agent in foam-mat drying of tomato. For this aim, density of foam-mats (green pea aquafaba+tomato puree) changed between 1.06 and 0.45 g/mL depending on the aquafaba concentration. They concluded that the porous structure of foams with lower densities resulted in higher drying rates and moisture diffusivities. All of the bioactive parameters are positively affected by foam-mat drying process. Redness (a*) value decreased with increasing aquafaba content ($p < 0.05$). Moreover, bio accessibility of phenolics and antioxidant activities were also determined using in vitro digestion. Using aquafaba as a foaming agent accelerated the drying period and improved bioactive characteristics of the powders. Paramasivam *et al*., (2022) [14] Prepared foam-mat dried red banana powder. In this study, red banana pulp was added with different gum derivatives as foaming agent (FA) (4 % w/w) viz., acacia gum (GA), carrageenan (CG) and gelatine (GE). Maltodextrin and carboxymethyl-cellulose were added as foam-stabilizers (FS). Effect of cellulose and gum derivatives on physicochemical, microstructural, and prebiotic properties of powder also analysed. The particle size (54.95 to 69.86 µm) of banana powder increased with gum derivatives addition. Paiva *et al*., (2023) [15] evaluated the effect of additives and drying temperatures on the powders obtained from the blend of tropical red fruits, such as acerola, guava, and pitanga. They prepared the foam formulation by mixing the pulps of the three fruits in equal proportions (1:1:1), all added with 6% albumin and 1% stabilizing agent as gum arabic, guar gum, gelatin. The final powder contains low levels of water activity and high levels of bioactive compounds, colors with a predominance of yellow, intermediate cohesiveness, poor fluidity, and solubility above 50% [16].

Conclusion

Foam-mat drying is an effective drying technique that has recently gained more attention because, it is not prone to some of the major issues associated with traditional drying methods, such as poor rehydration characteristics of dried products, unfavourable loss of sensory appeal, long drying times, handling issues caused by stickiness, poor flow or viscosity. This drying technique produces powders without harming heat-sensitive compounds. Low temperature drying makes this method low cost and economic.

Application of research: Foam mat drying method will be beneficial for perishable fruits and vegetables with a short shelf life. This method produces powder that can be used as an ingredient in bakery products and ready-to-drink beverages.

Research Category: Processing and Food Engineering

Abbreviations: P-Pulp concentrations
FMD-Foam mat drying, MC-Methyl cellulose

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