FOAMING IN FOOD SYSTEMS

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ABSTRACT

Aeration or foaming has a wide application in food and dairy industry and carried out by chemical, physical and biological means. Foam stability is the ability of protein to stabilize the foam against gravitational and mechanical stress.

Key words : Foaming, Food system.

INTRODUCTION

Foam is a colloidal system in which tiny air bubbles are dispersed in an aqueous continuous phase and foaming is a process of incorporation of air in the form of small air cells or bubbles. Foaming modifies various physical properties viz. consistency and texture. Processed dairy foods like ice cream, whipped cream, cakes, marshmallow, some traditional fermented products like idli, jelebi, dhokla *etc* are the examples of foamed preparations (Mansuett, 1975).

Mansuett, (1967) and Berry (1992) stated that air remains entrapped in food systems due to structural and functional characteristics of other ingredients in system. Therefore it is important to know the relation between the air present in food product and functional properties of ingredients associated with it. Mainly proteins are responsible for foaming properties in food. But every product containing protein may not entrap air in the form of foam. This all depends on the way of preparation and type of protein present. In addition to physicochemical properties of proteins, several factors affect foaming properties to a greater extent.

Stauffer (1990) studied that aeration or foaming has wide applications in food and dairy Industry and carried out by chemical, physical and biological means.

CHEMICAL METHODS OF FOAMING

Stauffer (1991) depicted that chemical foaming agents are also called as leavening agents.

Commonly food acids and soda are used in food industry. Various chemical foaming agents are as follows :

Ammonium Bi-carbonate : It is often used as supplementary leavening agent in bakery. It leavens the dough, when the temperature of the dough reaches 40^0C, in the early stages of baking. At this temperature it decomposes to give carbon di-oxide (CO_2). The reaction is as follows :

$$NH_4HCO_3 = NH_3 + CO_2 + H_2O$$

The potential of the gas formation by ammonium bi carbonate is dependent on its uniform distribution throughout the dough. Uneven distribution leads to "blow - out" in the product. The ammonia produced in the processes is water-soluble. Therefore the product will have typical taste of ammonia. Hence ammonium bicarbonate is applicable for low moisture product only.

Sodium bicarbonate : It is one of the most common leavening agents and is generally used in the granulated form. In most cases it is used along with acid to form carbon di oxide. It undergoes similar thermal decomposition as that of ammonium bi carbonate during early stage of baking.

$$2NaHCO_3 = Na_2CO_3 + CO_2 + H_2O$$

When sodium bi carbonate is used along with the acid it undergoes following reactions

$$NaHCO_3 + H^+ = Na^+ + CO_2 + H_2O.$$
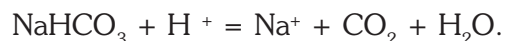
Potassium Bi carbonate : It is used, as the substitute to sodium bi carbonate. The mechanism is similar to that of sodium bi carbonate.

Leavening acid : Traditional leavening acids used in different form viz are vinegar, lemon juice, sour milk etc. Some newly developed leavening acids are mono basic calcium phosphate (MCP), sodium acid pyro phosphate (SAPP), sodium aluminum sulphate (SAP). List of leavening acids and their chemical reactions that occur when they dissolve in the water to liberate hydrogen ion are as follows.

principle that a batch to be aerated is pumped under high pressure into a mixed head, where at the same time gas under pressure is metered in. The degree of aeration can be controlled by amount of gas fed into the mixing head. These are used for aerated confectionaries like marshmallow, chocolate, coated bar, nougats etc.

3.   Hobart Mixers: Air is incorporated through

Mono basic calcium phosphate	$3Ca_2(H_2PO_4)_2 = Ca_3(Po_4)_2 + 3\ HPO_4 + H_2PO_4 + 7\ H^+$
Sodium acid pyro phosphate	$Na_2H_2P_2O_7 = Na + P_2O_7 + 2\ H^+$
Sodium aluminum sulphate	$NaAl(SO_4)_2 = Al(OH)_2 + 2\ Na + 2\ SO_4 + 3\ H^+$

While selecting them, the neutralization value (NV) and equivalence value (EV) of these acids must be taken in to consideration. NV can be defined as grams of the sodium bi carbonate neutralized by 100 gm of leavening acid. The EV can be defined as the grams of the leavening acid required to neutralize 1 gm of sodium bi carbonate.

Baking powder: It is the combination of chemical leavening agents, i.e. baking soda and leavening acid. It is available in two grades (Bennion and Stewart, 1943).

1.   Single acting baking powder : Gas evolution occurs only once eg. Anhydrous MCP + Baking soda.

2.   Double acting Baking powder : Here leavening action is desired over a range of the temperature eg. Anhydrous MCP + SAP. The SAP gives leavening in the middle of the baking process. In addition to baking soda and leavening acids, baking powder also contains various fillers and salts. Household double acting baking powder contains MCP. H_2O+SAP.

PHYSICAL METHODS OF FOAMING

Mizukoshi (1990) reveled that air is incorporated physically by setting the liquid or the solid solution to a violent motion. Equipments used for physical foaming are as follows.

1.   Planetary beaters: These are specially used for manufacture of aerated confections. This is batch operated and has capacity up to 600 liters. It is generally used for small-scale production.

2.   Continuous Beaters: These are based on the

perforated discs while mixing is going on. This is especially used for cakes.

4.   Votators : This is basically a scraped surface heat exchanger with scrapper blades with provision for air incorporation. The cooling media passes through the outer jacket and ice cream mix is fed in through the inner shell from one end. Air is simultaneously incorporated with the rotor (300-600 rpm) giving uniform dispersion of small air bubbles. The flow rate of the mix is so adjusted that the desired overrun is obtained as the mix moves from one end to the other.

BIOLOGICAL METHOD OF LEAVENING

Vekata et_al (1985) mentioned that yeast and bacteria are well known biological leavening agents. Yeast is used to carry out anaerobic fermentation to produce CO_2 and ethanol. CO_2 produced causes leavening in baking process. Ethanol may be used in wine making. Various yeast used for different purposes are :

S. cerevisae for Beer production

S.exiguous, Candida krusei, S.rouxii: for Bread preparation.

Torulopsis candida for Idli making.

Bacteria also help as leavening agent eg.

Leuconostoc mesenteroides: Idli

Lactobacillus species: sour bread.

FACTORS AFFECTING THE FOAM STABILITY

Foam stability is the ability of protein to stabilize the foam against gravitational and mechanical stress; however the Foamability or Foaming Capacity is the amount of interfacial area

created by protein. Phillips and Kinsella, (1987) observed various factors affecting the foam stability are pH, heat treatment, salt concentration, protein concentration, sugar concentration, whipping time, surface hydropbhobicity and lipid concentration.

1.   Effect of pH : Protein films exhibit higher shear viscosity and elasticity in the region of isoelectric pH. Therefore foamability and foam stability increases in the neighborhood of isoelectric pH. Grahm, and Phillips, (1979), observed the effect of varying pH on the foamability and foam stability for Whey Protein Isolate (WPI) at constant temperature (Figure 1). It was observed that the highest overrun and foam stability was recorded at pH 5 subject to change in temperature. Similarly highest foam stability was obtained at the same pH. Here in this case the foam overrun of WPI increased gradually as pH increases from 4 to 7. At pH 7 and above 7, foam overrun was decreased. This may be because of higher pH protein-protein interactions were inhibited due to the increased electrostatic repulsion. The highest foam stability was obtained at isoelectric point of protein. Thus the proteins form a strong film at the air water interface. (Phillips, and Kinsella, 1990).

Figure 1. Effect of change in pH on the % overrun for WPI
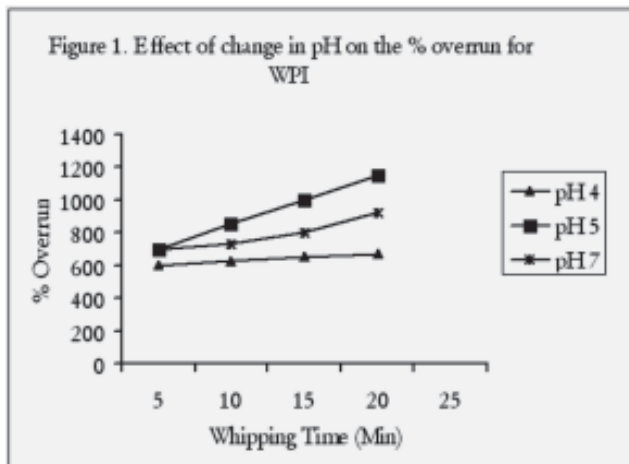
2.   Effect of Heat Treatment : Phillips and Kinsella, (1990) studied the effect of heat treatment on overrun of WPI at pH 5 as shown in Figure 2. The highest overrun is obtained at 55°C than at 25°C and 80°C. At higher temperature foam stability decreases due to greater exposure of hydrophobic residues which leads to interfacial coagulation of proteins. (Shrinivasan and Alain, 1997).
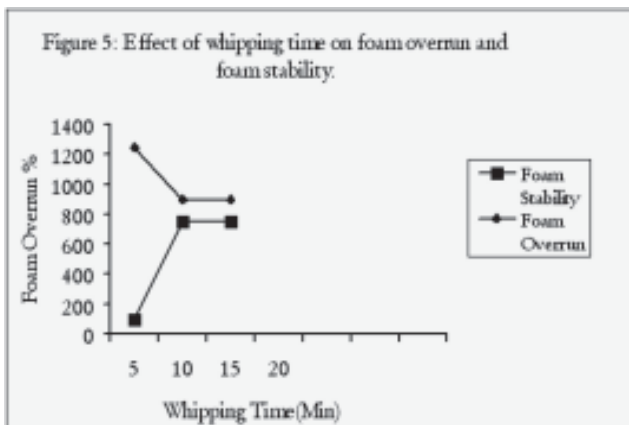
Figure 2: Effect of whipping time on % overrun at various temperatures at constant pH 5.
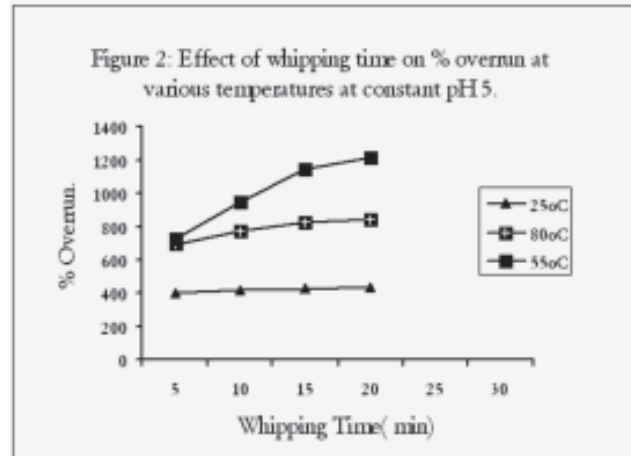
3.   Effect of Salt : Berger, (1980) and Thomas, (1981) studied the effect of salt concentration on surface concentration of ß-casein at air water interface as shown in Figure 3. Salt affects solubility, viscosity, unfolding and aggregation of proteins. Salt increases overrun and reduces foam stability. This is because of decrease in viscosity of protein solution (Phillips, and Kinsella, 1990).

Figure 3: Effect of change in surface concentration with respect to salt concentration
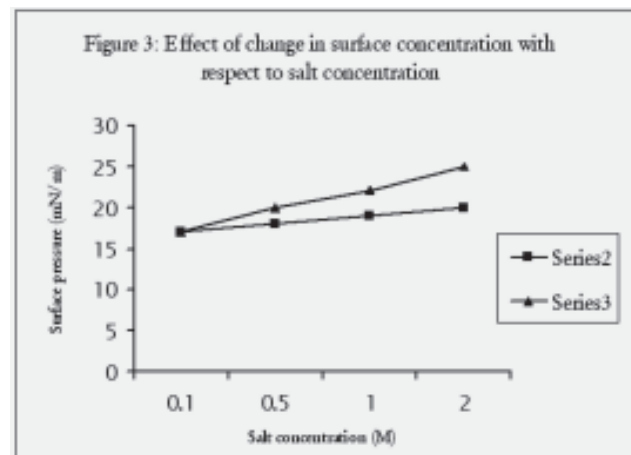
4.   Effect of protein Concentration : Carp, et al., (1997), explained the effect of protein concentration on foam expansion of soya protein as shown in Figure 4. Increase in protein as concentration increases both foam stability and foamability because of the viscosity effect, which produces thicker lamella film. If protein carries a large amount of liquid in lamella of foams, availability of liquid becomes limiting factor. Therefore foam volume decreases at higher protein concentration. (Grahm,and Phillips, 1979), and (Sahu and Panda, 1987).

Figure 4: Effect of protein concentration on the foam expansion for soy protein.
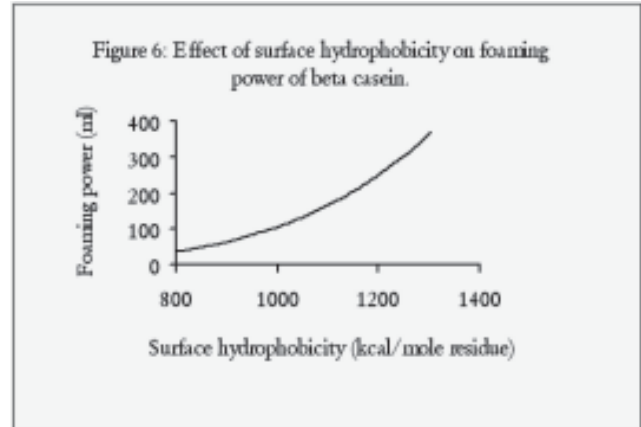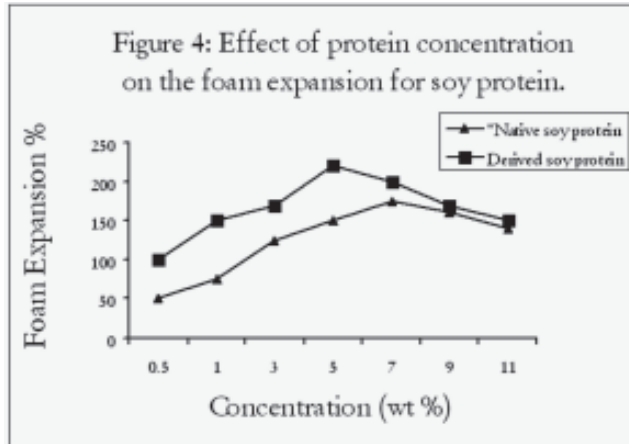
5.   Effect of sugar : Sucrose improves foam stability because it increases the bulk viscosity of the lamellar fluid, which reduces the drainage, and depresses the foam expansion. Hence during sweet preparation, sugar is added at the last when the foam expansion has already taken place.

Figure 5: Effect of whipping time on foam overrun and foam stability.

6. Effect of whipping time : Berger, (1980) and Shrinivasan (1990), studied the effect of whipping time on foam ability and foam stability of whey protein. (Figure 5). With 5 minutes of whipping higher overrun was produced because larger size foam bubbles are formed. However, foam stability was quite low, possibly because of the insufficient energy input and insufficient time to allow protein molecule to travel to the air water interface, unfold and interact with each other to form a strong film necessary to foam stabilization. Longer whipping time produces stable foams. (Phillips and Kinsella, 1990).

Figure 6: Effect of surface hydrophobicity on foaming power of beta casein.

7.   Effect of surface hydrophobicity : Grahm.and Phillips (1979) evaluated the effect of surface hydrophobicity on foaming power as shown in Figure 6. It was observed that surface hydrophobicity of about 1000 is sufficient to anchor the protein to air water interface i.e. each collision leads to adsorption at the interface. However once the protein molecules are adsorbed, its ability to rapidly decrease surface tension depends its average hydrophobicity and its ability to expose all hydrophobic residues at the interface. This means protein undergo conformational change at air water interface to increase the hydrophobic residues. (Phillips, and Kinsella, 1990).

8.   Effect of lipids and low molecular weight surfactants : Both of these destabilize the foam due to their higher surface activity. Because of the small molecule, surfactant exerts higher surface pressure. They displace protein from interface in competitive manner. This decreases film thickness and reduces the stability of foams.

Thus it is concluded that, the foaming properties are associated with texture and consistency of the product whereas foaming mainly occurs due to functional properties of proteins like pH, Heat, Concentration, Time of Whipping, Protein concentration and its conformation, polarity, molecular weight, etc. There is no optimal method for incorporation of air in the traditional foamed products where air is an acceptable criterion.

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