"FROTHING AS A FOOD PROCESSING TECHNIQUE"

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I. SUMMARY

In this work, two major topics have been studied using frothing techniques.

(I) Studies on the possibility of using frothing techniques for recovery of proteins from solutions have been conducted.

Using sodium caseinate protein, frothing studies on various possible factors affecting the enrichment ratio e.g. P^H, concentration, pre-heat treatment, have been carried out. It was found that, to recover protein as soluble protein, is rather more theoretical than practical.

However, further studies on frothing insolubilization techniques (i.e. to insolubilize protein by frothing) have shown that, it was possible to recover up to 65% of egg white albumin from solutions. The key factor governing the recovery efficiency was the stability of the protein prior to frothing operation i.e. the less stable the protein, the greater the recovery. For egg white, the most important single factor in promoting the recovery was the effect of P^H near the isoelectric point.

When the same techniques were applied to cheese whey, no froth precipitation was experienced even after various efforts

to destabilize the whey proteins just preceding the frothing process. A postulate has thus been put forward to explain the results.

(II) Experiments have been carried out to investigate the possibility of using frothing techniques for removing some undesirable substances in citrus juices e.g. excessive essential oil in citrus juice, naringin in grapefruit juice. Studies based on model systems have shown that, while a large proportion of essential oil would come out with the froth, appreciable amount of naringin could be removed only when a suitable surfactant was used. When the frothing techniques were applied to natural orange and grapefruit juices, it was found that, by removing a significant quantity of oil, some flavonoids and possibly some limonin, the flavour of the juices could be improved as confirmed by taste panel results.

(III) In addition, on the basis of the experimental evidence, a tentative theory and proposed mechanisms have been put forward for the removal of undesirable substances in fluid food product using surfactant.

II. INTRODUCTION

Recognition of the phenomenon of surface adsorption dates back to J. Willard Gibbs (29) who first pointed out that the concentration of a solute at the surface of a liquid could be greater than in the bulk of the solution. The thermodynamic relationship expressing this behaviour is usually referred to as the Gibbs adsorption equation. For a dilute solution of concentration C this equation is

$$\Gamma = -\frac{C}{RT}\frac{d\gamma}{dc}$$

where Γ is the excess concentration of solute per square cm of surface, as compared with that in the bulk of the solution, $\frac{d\gamma}{dc}$ is the rate of increase of the surface tension of the solution with the concentration of the solute, R is the gas constant, and T is the absolute temperature. According to this equation then, if $\frac{d\gamma}{dc}$ is positive, Γ will have a negative value, the concentration of the solute will thus be lower in the surface than in the body of the solution. This behaviour known as "negative adsorption" has been observed with some electrolytes. On the other hand, any solute which causes the surface tension of the solvent to decrease i.e. $\frac{d\gamma}{dc}$ is negative, will have a higher concentration in the surface than in the bulk of the solution, since Γ will be positive. In other words, a substance which decreases the tension at an interface will concentrate at that interface. This is known as "positive adsorption".

As the most common solvent in solutions is water, which has a high surface tension and most solutes reduce its value, hence the great majority of substances are positively adsorbed from aqueous solutions. This phenomenon of positive surface adsorption is the essential basis for foam separation techniques. As most surface active substances e.g. protein, organic salt and acid, alcohol, ester, etc. have the ability to foam. Thus when a solution containing surface active substances is foamed with a gas e.g. N_2, CO_2 or ordinary air, the foam will be richer in these solutes than the residual liquid. This foam can then be collected and condensed to produce a rich liquid product. Foaming, hence, permits the collection of interfacial material with ease in either batch or continuous systems. Successful foam separation is therefore dependent on the nature of the foam produced as well as on the adsorption characteristic of the system (59).

While ample information on theory and other relevant facts about surface adsorption and foam is readily obtainable from most text books or literature dealing with surface activity (9, 10, 26, 30, 42, 52, 72), information about foam separation theory has been relatively scarce. Shedlovsky (63) has reviewed in detail various methods for fractionation of mixture by foam separation. More recently an excellent review on foam separation, giving comprehensive details of general theory of foam separation, apparatus, application, examples of application together with 135 references, was published by Rubin and Gaden in 1962 (59). They state that, foam separation can best be applied to complex, heat sensitive, and chemically, unstable materials which cannot be readily separated by the common unit operation, distillation and extraction for example. Probably the greatest advantage of the foam separation techniques is its effectiveness at low concentration. Foam separation methods may therefore be used in those regions where other separation methods commonly encounter economical or practical limitations.

As a matter of fact, foam separation techniques have found innumerable applications in the past. Reports of publication can be dated back since the beginning of this century. However, if one tries to divide these reports broadly into two categories i.e. literature dealing with foam or foam separation in non-food field such as detergent, dye, organic acid and salt, ester, alcohol etc. and those which can be classified as food, one would find that enormous work has been done in the first category, which is beyond our interest in the present research project, hence, it is not intended to go through them here. On the contrary, reports pertaining to foaming of food either for separation or other purposes have been relatively few.

As early as 1934, Barmore (8) reported that egg white foam is more concentrated with a stabilizing agent such as acid and acid salts. However, this report and other similar ones on egg white foam (7, 33, 35) are mainly concerned with either stability or whipping characteristic of egg white foam.

Investigations of beer foam which is vital in brewing industry led to the discovery that protein is the main constituent of beer foam, and on foaming, protein tends to enrich in the foam phase (31, 51).

Also in a study of partially hydrolysed soybean protein foam, Perri and Hazel (55) found that the principal foam active ingredients were metaprotein and the protein fraction, and that the percentage of protein fractions were much higher in foam than in the residual liquid.

These two reports just mentioned, are again, the results of research aiming at improving foaming characteristic of foaming agents, rather than attempts to recover or remove any principal surface active ingredient by means of foaming.

Nevertheless, Ostwald and Siehr (53) described an apparatus and method for producing and separating foam from dilute solution, foam separation had first been successfully carried out with some inorganic compounds e.g. sodium oleate and aluminium stearate, and later they modified the original procedure to permit foam separation in a circulatory system. This new system was claimed to yield much greater concentrations of capillary-active substances. Experiments on potato and sugar beet juice resulted in complete separation of albumin after foaming for 18 minutes with CO_2.

Spengler and Dorbeldtz (65) attempted a full scale purification process of sugar juices by foaming separation techniques. They found protein enrichment in the foam was greater when CO_2 was used than with air. But there was not enough of a separation to make this a useful process to supplant the customary lime - CO_2 juice purification.

Arrazola (4),following a similar line, studied the foaming of fruit juices and saps by introducing of CO_2 as a possible industrial purification method. However, complete success has not been reported.

Frothing procedure has found useful applications in concentration and purification of enzymes (3, 6, 36, 43, 44, 54).

Foam separation has also been applied to fractionation of various proteins extracted from apples (21).

More recently Schnepf and Gaden (60) employed foaming methods to concentrate protein from very dilute aqueous solution of bovine serum albumin. They found that, all the results, at least, qualitatively, were in agreement with Gibbs adsorption equation, bovine serum albumin maximum enrichment ratio was found to increase with decreasing protein concentrations.

From the foregoing review of the literature, it can be seen that the foaming principle, is by no means an idea of recent origin, nevertheless, research work on application of foaming as a processing technique in food industry, apart from the few attempts cited above, has been relatively meagre. Therefore, it was the intention in this present research project to study the possibility of using foaming as a new processing technique, in addition to those conventional processing unit operations already exist in the food industry or to be used when the conventional methods are not economically or practically feasible.

This study was divided into three broad sections. In the first section, the effort was devoted to study of frothing as a possible process to recover valuable substances from dilute food waste liquor with special reference to protein food.

The second section of experimental work was dedicated to the study of frothing as an unit operation to remove undesirable matters from liquid solutions, with special emphasis on the possible removal of undesirable flavour compounds from citrus juices.

In the third section of the work, based on experimental evidence, a tentative theory was evolved to account for the removal of undesirable substances in fluid food products using surfactants and froth treatment.