ABILITY OF APHRON FLOTATION IN WHEY TREATMENT

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ABSTRACT : *Whey contains more than half of total solids present in the original milk, which includes 20% of the proteins, most of the lactose, minerals and water soluble vitamins. In this study, selective separation of whey components by Aphron flotation (separation of ultrafine particles by micro- bubbles) has been investigated. It has been shown that it is possible to recover valuable components of whey by flotation method instead of vaporization.*

KEY WORDS : *CGA, Aphron Flotation, Whey, Selective Separation, Lactose, SNF (Solid Not Fat), Protein.*

INTRODUCTION :

Whey and Current Whey Processing :

Milk is composed of 87% water, 13% solid materials which includes fat, protein, lactose, minerals, and vitamins A , B_1 , B_2 , C , and D. Milk is the raw material for the production of cheese.The effluent of cheese-making facilities is called "whey" which includes more than 50% of the solid materials present in the original milk. Table 1 shows a typical whey composition [1].

In general, the production of one ton of cheese usually yields eight tons of whey. According to the data released by the Iran Milk company, more than eighty thousand tons of whey has been produced in Iran in 1991.

One of the main difficulties of whey disposal is its high value of the BOD (Biological Oxygen Demand) which is usually about 35000- 45000 ppm [2], that is, 1 ton of whey has a polluting strength equivalent to the sewage produced by 450 persons. On the other hand there has been a recognition that the proteins and lactose in whey are too valuable nutrients to be wasted.

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Table 1 : Whey Composition

Component	g / L
Total suspended solids	67.00
Protein (*)	6.20
NPN	0.27
Lactose	52.40
Minerals(Ash)	5.20
Milk fat	0.20
Phosphate	0.50
Calcium	0.40
Sulfate	0.60
Magnesium	0.80
Sodium	0.50
Potassium	1.50
Chloride	2.00

(*) =(TN - NPN)(6.38);
TN =Total Nitrogen
NPN =Non Protein Nitrogen
pH =5.9

To take advantage of these nutritional and functional properties, many processes have been investigated in order to recover whey components in an acceptable fashion. Whey fat is recovered by centrifugation in a described process [3] and the remainder is then concentrated for crystallization of the lactose. The resulting liquor is subsequently dried by spray drying to recover proteins.

The concentrated whey, which contains about 64% TS, is prepared in multistage concentrator and it is used for feeding of cattle.

To recover whey proteins, it is acidified to pH about 4.6 and then warmed to boil by steam injection. The protein begins to coagulate from 63°C and sediments after boiling. 60% of sediments consist of proteins. The dried protein is used instead of egg in some food industries [2].

A process has been described for producing lactose by methanol extraction of whey after its cooling [1]. The clarified liquid is acidified by HCl. The lactose crystallizes after cooling with a yield of 65-70%. The recovery more than 95% is possible by using cationic and anionic ion exchangers.

The economics of such processes for a dilute solution as whey is likely to be unfavorable because a lot of cheese plants have whey disposal problems. The Aphron flotation technique, put lined in this paper, is proposed as a suitable canditate to solve the problem.

Fine Particle Separation from Liquid by Flotation:

Froth flotation is a common and important separation process in mineral processing. Dissolved air flotation is mainly used in waste water treatment. In this method, excess air is dissolved in water by increasing the pressure (super saturation). When water that is super saturated in air is exposed to ordinary condition (atmospheric pressure), air changes into fine bubbles which rise up and carry suspended solids to the water surface.

Different aspects of flotation process have been investigated by many researchers. But flotation has a great limitation; when diameter of particles are less than 10μm, efficiency of separation is sharply reduced and for particles less than 1μm, it fails.

Ahmed and *Jameson* [4] studied the effect of bubble and particle diameter (d_b , d_p) on the interception efficiency (E_c). They found:

$$E_c = d_p^m / d_b^n$$

where : m= 1 - 2 and n= 3.5 - 4.

In ordinary flotation, the diameter of bubbles are about 0.1 to 10mm. From the above equation, one can clearly conclude that smaller bubbles (as an Aphron bubble) result in increasing interception efficiency.

Aphron Flotation :

Aphron is the name proposed by *Sebba* in the second world congress of chemical engineering in 1981 in *Montreal, Canada* for a colloidal gas Aphron dispersion, CGA, [5]; but the technology of mass production of CGA was developed in 1986 [6].

The bubbles appear to have an average diameter of about 50μm. Each Aphron has a shell with average thickness of about 7μm (Fig. 1).

The most striking feature of the Aphrons are their stability, which lets them be generated externally to their point of use, and then to be transported by pumping.

Behaviour and morphology of Aphrons are studied elsewhere [7]. The number of Aphrons that exist in one droplet of CGA is much more than those shown in Fig. 1.

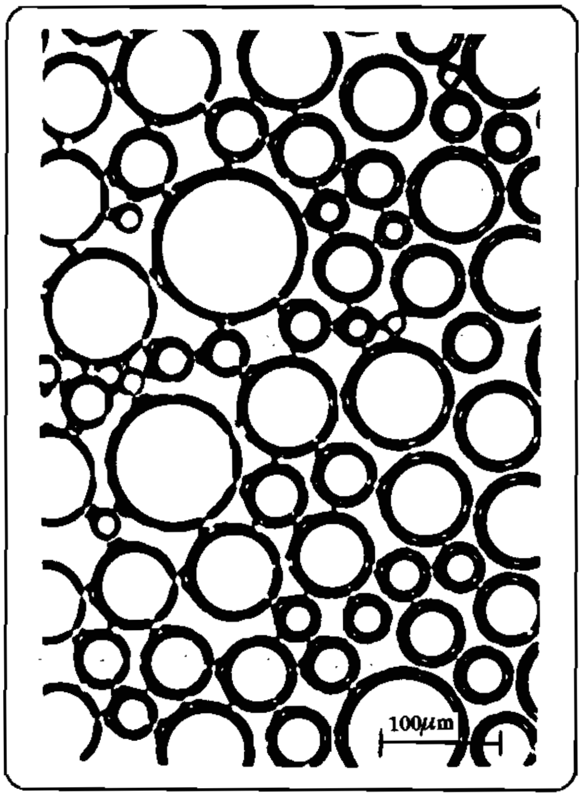

Fig. 1 : Colloidal gas Aphron dispersion.

EXPERIMENTAL :

Generation of Aphron Dispersion :

The colloidal gas Aphron dispersions were generated in an apparatus described by *Sebba* [6]. Fig. 2 shows the Aphron generator.

The apparatus consisted of a thin metal disk 5cm in diameter mounted on a vertical shaft. The disk was immersed 2cm below the liquid surface. The shaft was driven by a 0.1HP motor at 6500rpm. Two baffles prevented the formation of a whirlpool- vortex. The distance between baffles and the wall is 1cm.

For generation of Aphron, a 3L beaker is initially filled with 1L of distilled water to which about 1g of a surfactant is added. The high shear force between disk and liquid generates about 3L of Aphron dispersion in a few minutes.

Fig. 2 : Aphron generator.

Measurement of Whey Components :

An advanced analytical unit, *Milkoscan* 133, V305 GB has been used to measure the concentration of whey components. This unit measures the fat, protein, lactose, total solids, and total solids without fat content of the samples.

The composition of three samples were measured in each run. They are foamate, dilute and initial solution samples. The dilute sample is the initial solution after collection of foamate.

Flotation Tests :

The experiments were carried out in a batch mode. After Aphron generation, the Aphron bubbles with the fine particles cream to the top of the sample solution. The important factors in each run are the time of Aphron generation (t_R), time of foam drainage (t_d), concentration of surfactant (C), and pH.

Normal NaOH and HCl have been used to modify the pH of the samples.

It is obvious that longer drainage times result in less wetted foams, therefore, drainage time can control the water content of foamate.

RESULTS :

Many experiments were done to study the effect of parameters on the separation processes. The reported results in this paper have been obtained under the following conditions:

C=0.5 g/L ; pH = 6.4; t_d = 27min; t_R = 260sec.

The surfactant was tetradecyl trimethyl-ammonium bromide.

Fig. 3 illustrates the change of total solids (TS), total solids minus fat (SNF), lactose (LACT), FAT, and protein (PRO) in foamate as a function of pH between 2.4-2.8. Fig. 4 illustrates the change of those parameters versus pH in dilute and initial whey solution.

In Figs. 5 and 6, the change of the said parameters in whey, dilute and foamate vs. pH in the range of pH= 2 to pH= 6 are shown. Effect of drainage time (t_d) on foamate and dilute whey are shown in Figs. 7 and 8, respectively.

Figs.9 and 10 show the effect of Aphron gene- ration time (t_R) for both foamate and dilute whey. The effect of the surfactant concentration on foamate is shown in Fig. 11, and of the dilute in Fig. 12.

DISCUSSION :

It is important to note that there are two mechanisms which control the separation of fine particles from dispersions. The first mechanism is entrainment which imply the entrapment of the particles among the bubbles. The second mechanism is the adsorption of the fine particles on the surface of the bubbles whose creaming results in the separation of particles from dispersion.

The length of drainage time is the source of differentiation between the two mechanisms.

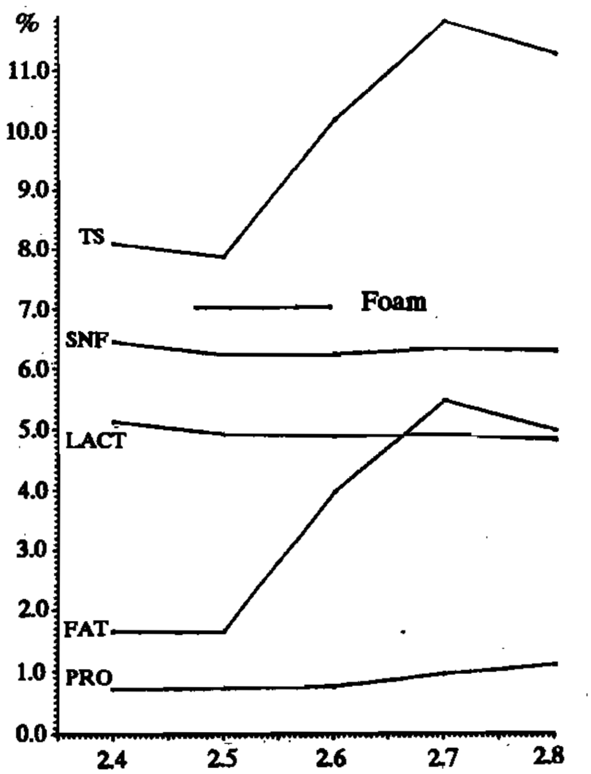

Fig. 3 : Parameters variations versus pH

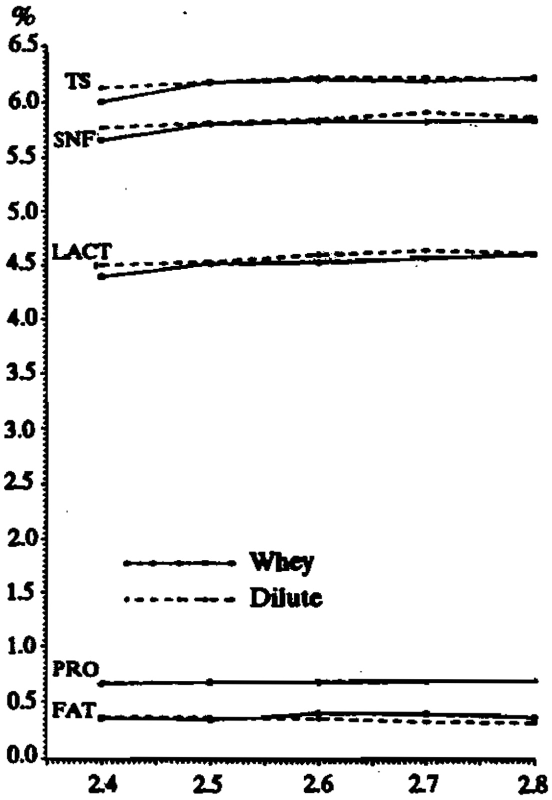

Fig. 4 : Parameters variations versus pH

When the drainage time is increased the effect of entrainment mechanism decays and adsorption controls the concentrating of particles in the foamate.

The two mechanisms can be differentiated from another point of view. Only partial separation can be achieved in the first mechanism, but complete separation may be approached at least under the ideal conditions in the second mechanism.

Both the degree of separation and the weight of the separated materials (recovery) are important in flotation. In the present study attention was focused on the degree of separation. By increasing the drainage time, a dry foamate is obtained and therefore, the weight of foamate in comparison with the dilute becomes very small. This is possible only with batch experiments. Comparison of Figs. 3 and 4 shows that there is not a significant separation in the range of pH 2.4 to 2.8.

Fig. 5 indicates that where pH is above 3 the fat is decreased and the lactose is increased in dilute. This finding is supported by the decrease in the total solids(TS)and constancy in the solids not fat (SNF) curves. This indicates that in this range, fat is omitted. The changes are boosted in Fig. 6 where the changes in parameters for foamate corresponding to the Fig. 5 are shown. It is observed that the best pH for removing the fat is 3 and the rate of removing is decreased upon increasing pH while the lactose and protein are concentrated slightly in foamate up to pH= 5. But the protein is the main component which is separated at pHs above 5 and becomes maximum at about pH 6. It is observed that in this case, there is a tendency for the lactose to concentrate in the dilute rather than in foamate.

The effect of drainage time on separation has been shown in Figs.6 and 7.As it is already men mentioned, increasing the drainage time enhances the mechanism of adsorption of particles on surface of the bubbles. It seems that the adsorption energy between the fat particles and the Aphron bubbles are the highest and that between lactose and bubbles are the lowest. However, the adsorption energy for all three components are large enough not to be washed out by drainage.

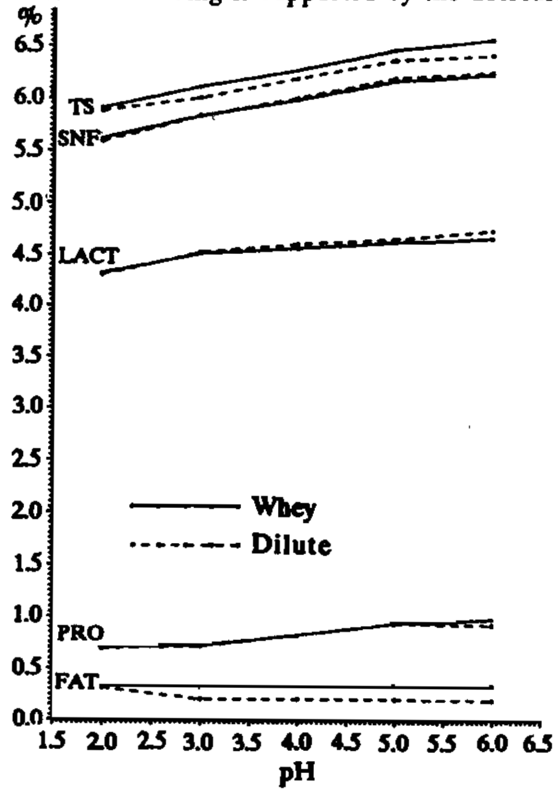

Fig. 5 : Parameters variations versus pH

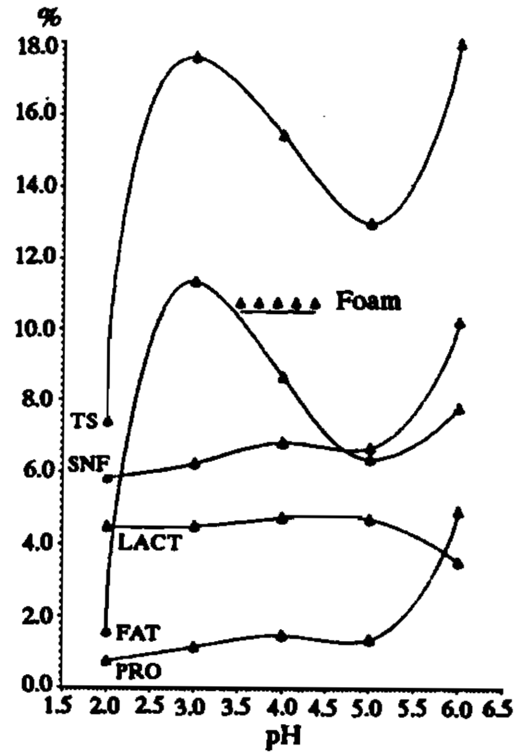

Fig. 6 : Parameters variations versus pH

Figs. 8 and 9 illustrate the effect of Aphron generation time on the said parameters. They show that the protein and SNF increase but the lactose decreases slightly upon increasing the generation time. This indicates that the surface adsorption force between protein and bubbles is

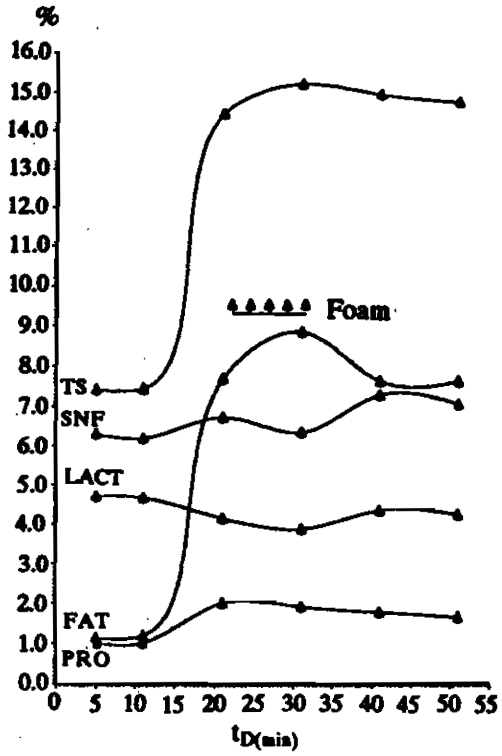

Fig. 7 : Parameters variations versus drainage time.

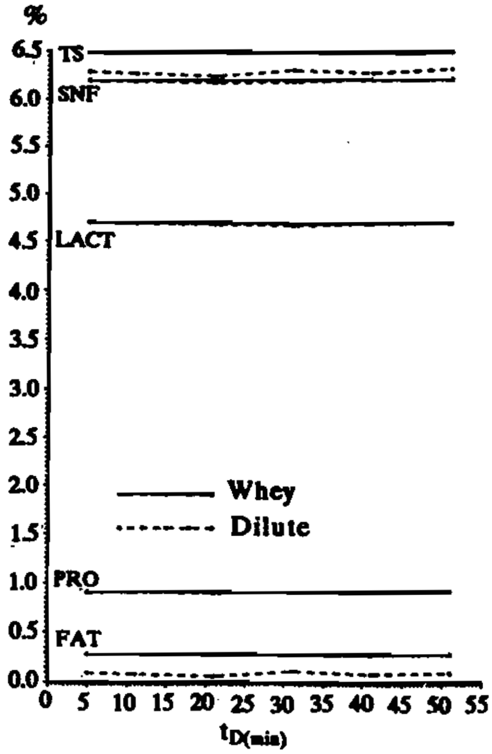

Fig. 8 : Parameters variations versus drainage time.

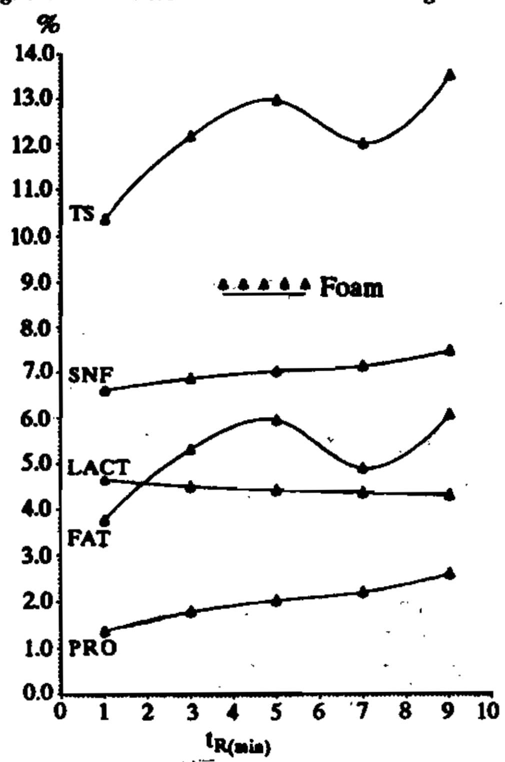

Fig. 9 : Parameters variations versus Aphron generation time.

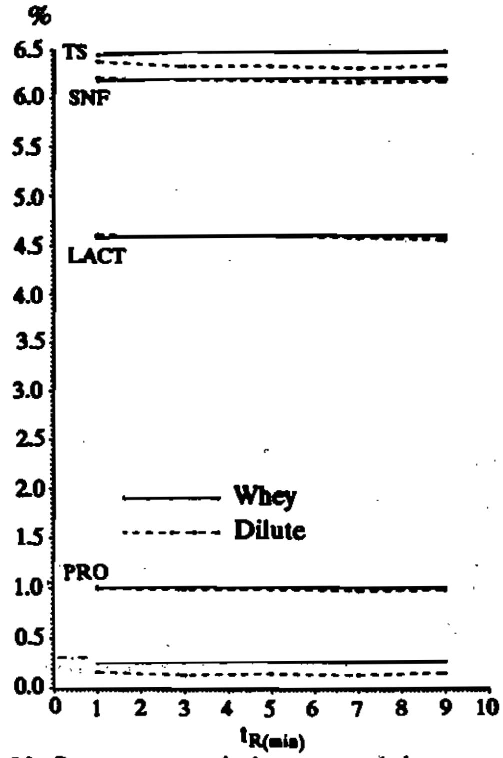

Fig. 10 : Parameters variations versus Aphron generation time.

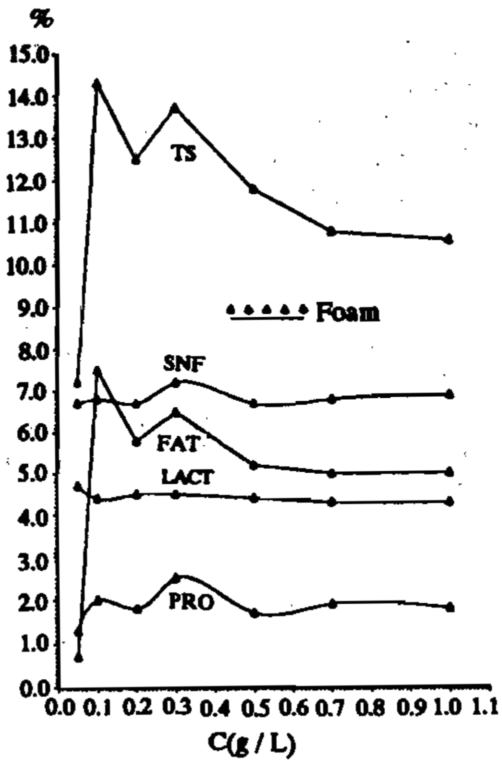

Fig. 11 : Parameters variations versus surfactant concentration.

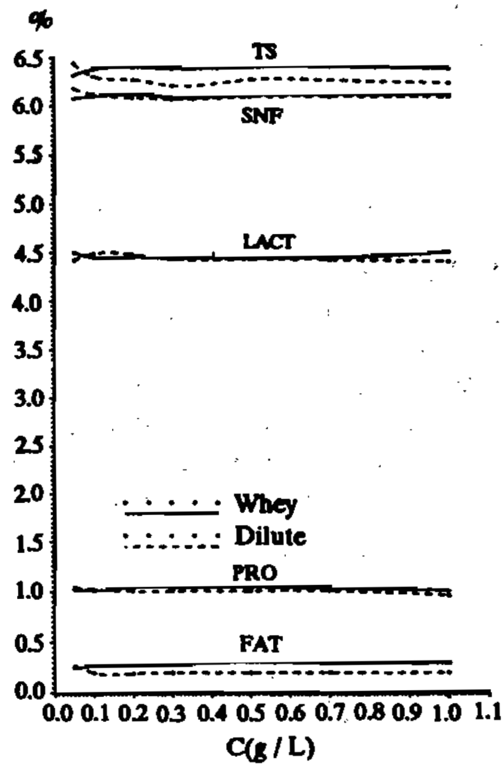

Fig. 12 : Parameters variations versus surfactant concentration.

higher than that of the lactose.

The effect of surfactant concentration on parameters are shown in Figs. 10 and 11. Although Fig. 10 indicates that the separation of the fat decreases with increasing the surfactant concentration, a careful examination of Fig. 11 illustrates that the variation is not high and the rate of change in parameters becomes negligible upon increase in surfactant concentration. It has already been reported [7] that the morphology and behaviour of Aphrons do not change when the concentration of surfactant exceeds about 1g/L. It is interesting to note that the separation of the fat is high for very low surfactant concentrations. This may be due to conversion of small bubbles to big polyhedral, as *Amiri* [8] observed and reported. The fat molecules can easily flocculate and big polyhedral foam presumably lift them to the surface.

CONCLUSIONS :

This work outlines the selective separation of whey components by Aphron flotation technique for the first time in the world. Even though this research is a preliminary step in developing a new method for the recovery of valuable suspended food materials from whey, it indicates the need for the further extensive investigations. The results clearly show that the selective separation of whey components is possible even by controlling some simple parameters such as pH or drainage time.

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Notations :

C =Concentration of surfactant
d =Diameter

LACT = Lactose
PRO = Protein
TS = Total solids
SNF = Total solids minus fat
t_D = Time of drainage
t_R = Time of Aphron generation

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