PROCESS - PRODUCT INTERACTIONS

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ABSTRACT

The objective of this work is to demonstrate the positive influence of process conditions on the product qualities such as stability and viscosity. Two common processes such as emulsification and macromolecular dispersion are investigated. The effect of processing conditions such as the distribution of fluid intensity on the product qualities like physical stability, particle size and viscosity are studied under various process conditions. In this context, the underlying physical principles are explained. Practical system such as icecream mixes, fruit pulps, fruit juices and thandai syrup are used for experimentation. Further, it is also explained how one can utilise these results for a fruitful R&D with an objective to save on expensive raw material like stabilisers and emulsifiers and also on the capital cost of equipment.

Introduction

Food products have several ingredients. The physical chemistry is generally complex. Basically, the process foods contain sugars (or cabohydrates in general), proteins, fats (or Oils) and water. Together with these, there are some stabilisers, emulsifiers, colours and flavours. Each product is designed to have a certain consistency or viscosity.

A product designer is generally aware that he is not going to get the final product just by mixing all the ingredients. He knows that they need to be processed properly. However, rarely, does he go one step further and ask how one can use processing as a powerful tool in designing product properties. And how one can obtain stability and rheology mainly by the choice of proper process conditions. Such is the topic of this work.

Table 1. Experimental Conditions

No.	Working Volume	Impeller Dia (mm)	Motor Speed (RPM)	Tip Speed (m/Sec)
1	2 lit.	50	6000	13
2		75	6000	20
3		50	1500	4
4		75	1500	6
5	5 Lit.	50	6000	13
6		75	6000	20
7		75	1500	6
8		110	1500	8

2) Experimental

2.1) *Setup and Conditions*

Experimental setup is described in Fig. 1. This specially designed setup consisted of a high shear unit that was capable of up and down motion. The shaft was directly driven by a single phase motor of either 1500 rpm or 6000 rpm. On the shaft, impellers of different sizes could be fixed at the time of experimentation. Two impellers, the description of which is given below, of diameter of 50 mm and 75 mm, were used. Working capacity was kept at 2 and 5 lit. Experimental conditions are summerissed in Table 1.

Impellers were specially selected for high efficiency emulsification and macromolecular dispersion. These work on a principle that

—a high level of axial dispersion is created in the vessel and

—each fluid element passes through a specially created high shear zone.

The high shear zone in three ways, namely :

—by creating a converging flow

—by creating a high shear rate near the impeller

—by physical cutting action of the impeller.

It was intended to study some typical food systems where the physical properties of the final product could positively be varied by the processing conditions. The composition of the system investigated is given in the Table 2.

2.2) *Measurements*

For physical property measurements, three techniques were used, namely i

—Particle size measurements with optical microscope

—Physical stability measurement by visual observation

Table 2. Composition and Solid Contents of System Studies

		Composition		(wt %)	Brix°
1)	Processed Milk	SMP	—	28	40° Brix
		Butter	—	28	
		GMS	—	0.3	
		Water	—	44	
2)	Ice-Cream Mix	Butter	—	12.3	37° Brix
		Sugar	—	14	
		SMP	—	12	
		Guar Gum	—	0.5	
		GMS	—	0.3	
		Wate	—	61	
3)	Thandai Syrup	Extract	—	35	70° Brix
		Sugar Syrup (80°)	—	65	
4)	Mango Pulp	Mango Pulp	—	100	—
5)	Mango Beverage	Pulp	—	15	15° Brix
		Sugar	—	15	
		Water	—	70	

—Viscosity measurements with capillary viscometer.

All measurement were done at the room temperature 25 to 30°C.

3) **Process and Results**

The processes that are investigated here, are :

—Emulsification and
—Macromolecular dispersion.

3.1) *Emulsification*

The systems studied were processed milk and ice cream mix. In both the system it is basically the emulsification of butter fat in water, stabilised by milk proteins or other stabilisers. In both cases, the following steps were taken :

1) Butter was melted separately and GMS was mixed in it.

2) Water was heated to 80°C,

3) Solid milk protein were added to it and thoroughly dispersed under the same experimental conditions as for the emulsification (See table 1). In case of ice-cream mix, sugar was mixed with SMP before addition. This prevented the immediate agglomeration.

4) Maintaining the above conditions, the

molten butter was added to the system. Total process time was 20 min.

Immediately at the end of the experiment, samples were drawn. Droplet size measurements were done by observing the particles under a microscope: It was observed that under the experimental conditions of (1) and (2), most of the droplets were below 5 micron. Only 20 to 25% of particles were between 5 to 25 micron. When the tip speeds were reduced in the case of experiments (3) and (4), it was observed that particle sizes of 50 to 100 micron were also present. Thus, high level of shearing in the case of experiments (1) and (2) definitely brought most droplet under the 5 to 10 micron level.

3.2) Macromolecular Dispersion

In order to investigate the macromolecular dispersion, three systems were investigated, these being :

—Thandai syrup

—Mango Pulp and

—Mango Beverage (Juice).

All dispersions were done at the room temperature under the experimental conditions described in Table 2. Briefly the procedure is described below.

Thandai Syrup

First the sugar syrup was made. The thandai extract separately prepared was then mixed in this under the above noted experimental conditions for 30 min.

Mango Pulp

The pulp of fresh mangoes was stirred in the above noted unit for 5 min.

Mango Beverage (Juice)

Mango pulp and sugar were added to the water and dispersed, for 15 min. Samples were withdrawn at every 5 min for viscosity measurements.

Particle Size

In all the above cases for experimental condition (1), (2), (5) and (6), the maximum particle size observed under the microscope was about 10 to 15 micron. Roughly, about 50% particles were in the range of 5 to 15 micron The rest were all below 5 micron.

Physical stability

Stability was also studied for experimental setup (1), (2), (5) and (6). Mango pulp was canned in 850 g can and mango beverage and thandai syrup were bottled in 1/2 and 1 lit. bottles. These were stored at the room temperature. These samples were then observed if there was any separation between the solids and liquid. The observations were done over a period of six months. The pulp was found to be homogeneous even after six months showing no sign of separation. The thandai syrup and beverage showed a very little separation after three months. In thandai syrup about 10% of liquid was observed at the bottom. In beverage, it was not more than 1% at the top. Further, these remain so for one year.

Viscosity

Viscosity measurements were done by a capillary viscometer. The reading was in 'Sec'; the time required for the flow of a certain volume of liquid. Seven readings were taken for each condition and time. Viscosity of distilled water was then measured. The ratio of liquid viscosity to that of the viscosity of distilled water was plotted against process time in Figure 2.

The figure clearly shows the effect of shearing level and conditions on the viscosity.

4) Discussions

The process of Emulsification and dispersion are very much influenced by flow field and the fluid intensity. The physical phenomenan as certained with these processes have been elaborated previously (1), (2), (3) in detail. In this context, the results of the present work are examined below.

Emulsification

In emulsification, it is essential to deform a large drop into a ellipsoid or better still into a thread. The deformed drop then breaks when the applied forces overcome the surface forces. Smaller droplets are obtained when the drop is elongated into a long and thin thread. The long thread then breaks as a result of surface instabilities. Rheological properties of surface and the bulk also become important. These physical aspects are quantitatively discussed in our previous paper.[1]

The surface properties are modified to our requirement by choice of proper emulsifier. Temperature is also an important factor in this respect It is important also to note that one should make sure that the drops once formed do not undergo coalescences. The stabilisers are added for this purpose.

The roles of emulsifiers/stabilisers are quite definite. However, their requirement very much depends upon how the other process conditions are. The conc. of emulsifier required is lower if the flow field and the impeller action is more suitable for the process of emulsification. If dispersion of stabiliser is properly done it gives higher viscosity to the continuous medium and thus a stable emulsion is obtained at a lower stabiliser concentration. Traditionally, emulsification of processed milk and ice-cream mix is done in a Homogeniser. In Homogeniser, a high level of turbulence created in a small channel where the droplets break into smaller droplets. Apart from this being an expensive equipment, the energy requirements are very high. The high shear impeller that we have used here operates at low energy level. The principles are noted in the section 2. These do give fairly low particle size. Of course, they can't match 'Homogenisers' in all the cases But these can surely be substituted for a homogeniser in certain cases. Further, using these for preemulsification one can surely save substantial energy, even when a homogeniser is used.

Macromolecular Dispersion

Carbohydrates and Proteins are the major ingredients of the systems investigated. Part of these may be water soluble. In any case, in the raw pulp they are aligned in a certain way, giving a fibrous mass. The macro molecules are in globular, agglomerated and fibrous state. Such particles tend easily to settle. Also they make the product unpleasant to eat. A process is therefore required by which these globules, agglomerates and fibres are broken down into smaller particles to form a homogeneous mass.

The improvement in the physical stability is obtained for two reasons, namely :

— particle size reduction

— increase in the viscosity of the liquid surrounding the particle.

The reduction in the particle size causes reduction in the gravitational forces acting on them. And the increase in the viscosity gives more resistance to settling The stabilising effect of mamko's high shear unit is thus explained.

All particles assume sizes in a narrow range. Further the globules and agglomerate lose their identity. Thus the product also becomes smooth to eat.

Dramatic viscosity increases in Mango beverage are obtained by processing. These are shown in Fig. 2. The positive consequences of such viscosity increase on the emulsion stability are noted above. The increase in viscosity also gives a thickening effect, which may be felt during consumption of the beverage. This suggests that concentration of stabiliser or thickners could be reduced in many cases.

Physical reason for the dramatic effect on the viscosity could be found in the fact that both carbohydrates and protein molecule can bind a definite quantity of water with them even when they are not completely soluble. When tney are soluble, they are known to bind and immobilise water around them As globules agglomerates, fibres are broken down, more and more of the particles and molecules are exposed to water and thus the amount of bound or immobilised water increases. The larger is the volume of immobilised ingredients tne higher is the viscosity. The relationship is almost exponential[3]. Thus, by properly dispersing macromolecules, one can get the thickening effect.

5) Conclusion and Implications

— It is shown that in emulsion and dispersion preparation, attention should be given to the process conditions and equipment designing. By proper choice here, one could reduce the requirement of emulsifier, stabiliser and thickners.

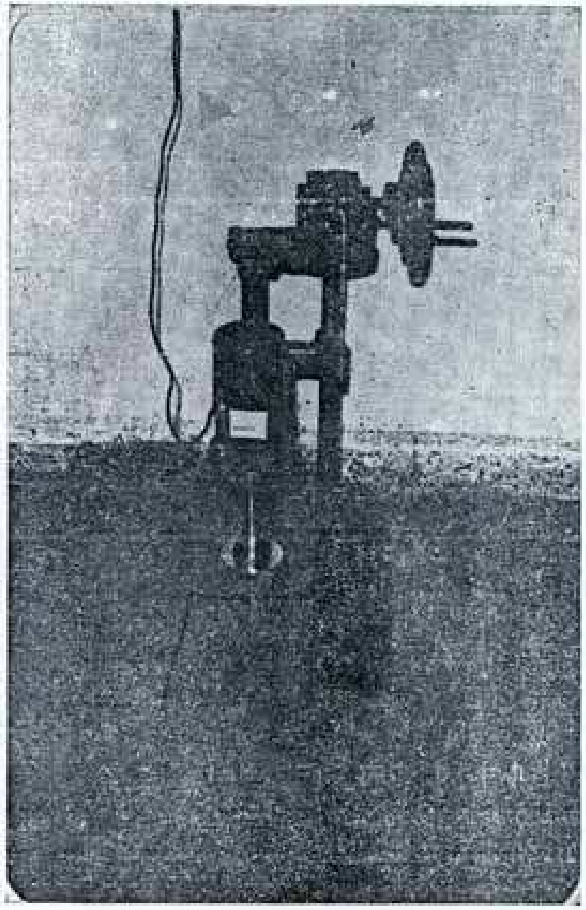

Fig. 2 : Experimental Setup

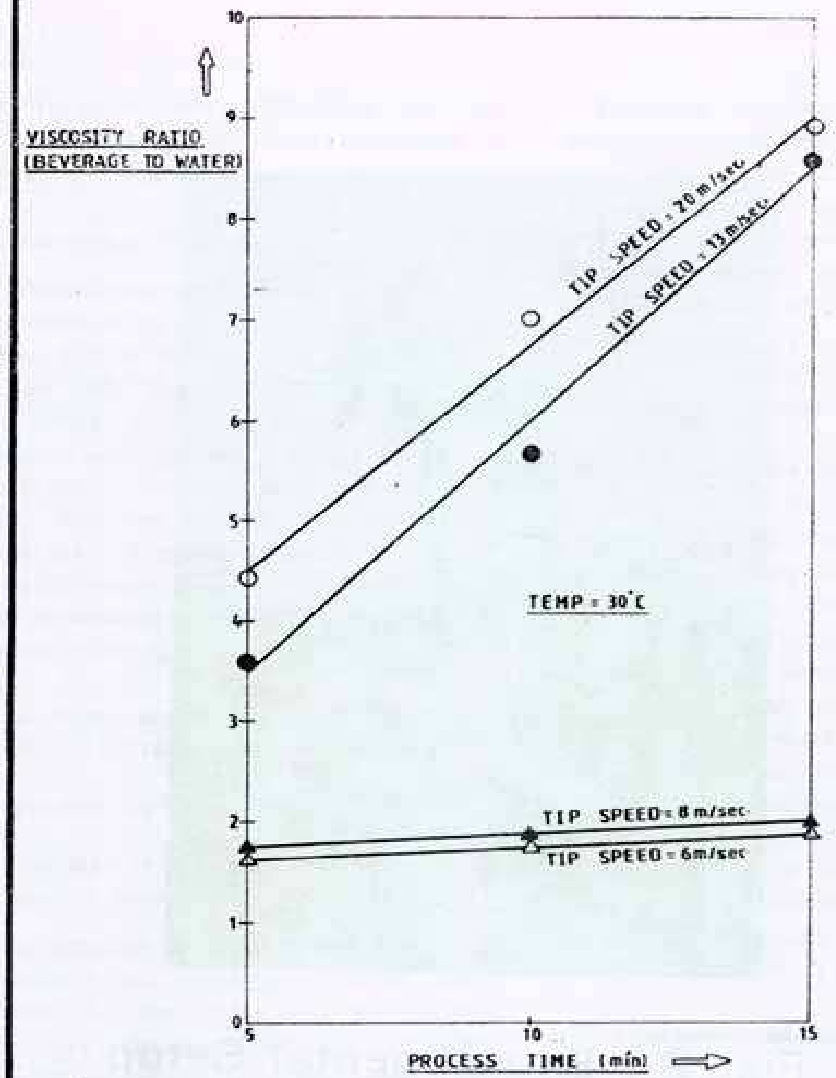

FIG. 2: EFFECT OF PROCESSING ON VISCOSITY OF MANGO BEVERAGE

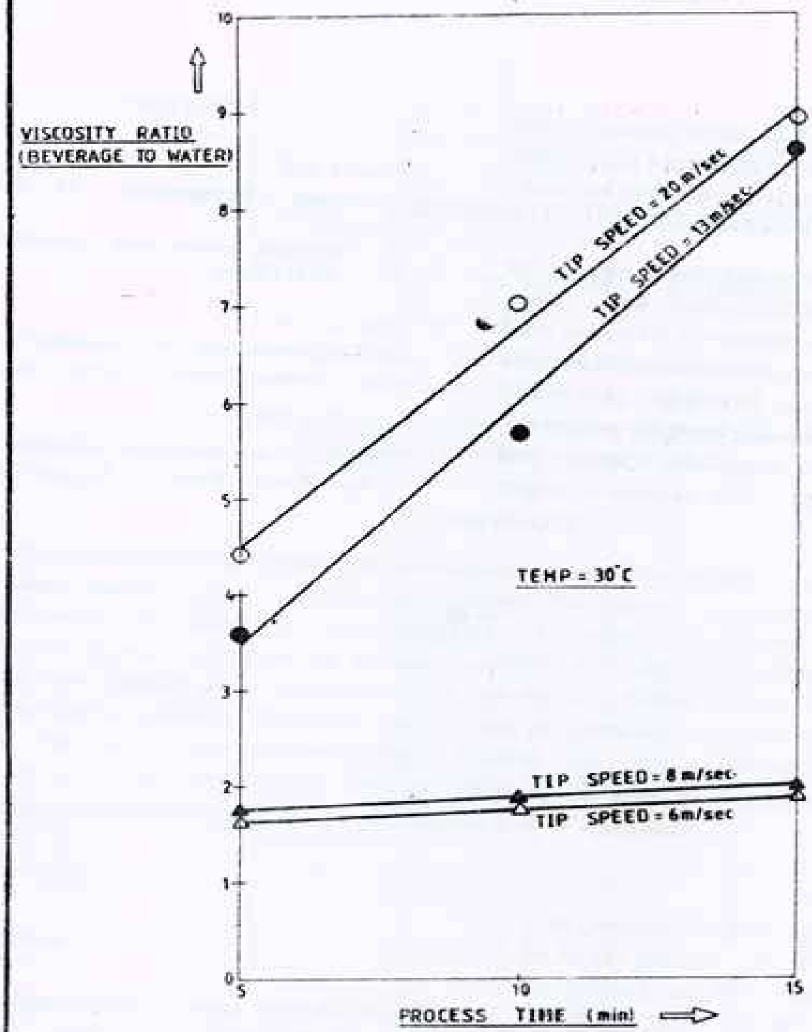

FIG-2: EFFECT OF PROCESSING ON VISCOSITY OF MANGO BEVERAGE

— It is implied that other process conditions such as temperature differences, sequence of addition may also be modified for a positive effect.

— It can be suggested that even in the process of crystallisation, flow conditions will have substantial influence. And by proper choice of these conditions the Consistency and Rheology of the final product can be manipulated positively. Especially, in chocolate, butter and icecream industry this concept is worth looking into.

REFERENCES

1. Chavan V.V.
'Processing Fundamental of Suspension/Emulsion'
Jl. Dispersion Science and Technology Vol. 4 No. 1 P. 47 (1983).

2. Chavan V.V.
'Mixing Technology—Fundamentals'
Chem. Product Finder P. 25 Dec 1986.

3. Chavan V.V.
'Suspension and Dispersion in Reactor'
'Chem. Product Finder' P. 85, June 1987.

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