Efficiency of a Milk Homogenizer Valve

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Homogenization of milk products has a history of more than 50 years. Its theory has not been very well understood. Several recently published articles relative to the mechanism of homogenization are listed in the appended bibliography for reference (1, 2, 4, 5, 6, 7).* The bibliography is by no means complete, since it is not the aim of this paper to review the literature.

Homogenization, specifically, is an operation that tends to stabilize the suspension of milk fat in milk by reducing the size of fat globules. In some milk products, a higher viscosity, which helps stabilize the fat, might also be effected by homogenization. The homogenizing action is obtained most commonly by forcing the milk under high pressure through a relatively small opening. Acoustic waves have also been reported successful for homogenizing milk. However, we are concerned only with the continuous pressure homogenization in the discussion in this paper.

The homogenizing opening is usually manufactured in an adjustable form resembling that of a poppet valve. Some commercial makes are in the form of an aggregate of small elements such as wires or round shots. In an investigation carried out at the Carnation Company research laboratory, most of the homogenizing openings were in the form of fixed orifices. Some of them were round holes ranging from 0.006 to 0.023 in in diameter and 0.02 to 0.25 in in length. Some of them were just narrow slits ranging in width from 0.001 to 0.006 in. Some others were like the poppet valves but had the seats narrowed down to almost nothing. Though they may not look like valves any more, for the sake of convenience, they will all be referred to as homogenizer valves.

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*Numbers in parentheses refer to the appended bibliography.

A Report on Experimental Data Taken in Connection with a Laboratory Study of the Efficiency of Valves Used in the Homogenization of Milk

Using these various kinds of valves, some factors relative to the design and operation of a homogenizer valve were investigated. They were

- The type of flow
- The length of treatment time

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· The dimensions of the valve
· The back pressure applied to a homogenizer valve.

By using orifices of fixed dimensions and a pump of adjustable capacity, it was possible to organize an experiment such that the effects, due to some of the various factors, could be individually evaluated for significance. Others require statistical methods to extract and evaluate them. The influence of a factor on the efficiency of a homogenizer valve was judged by its effect on the stability of the fat in the treated milk.

Some of the experimental results relative to the effect of the type of flow on valve efficiency are presented in Fig. 1. It is obvious from this graph that, if the flow of milk in the valve had a Reynolds number below 2000, only slight improvement of the stability of fat was obtained. This improvement in stability was independent of the Reynolds number. As the Reynolds number went over 2000, the homogenizing effect increased steadily. It is rather interesting that this particular Reynolds number of 2000 is about the dividing point between laminar flow and turbulent flow.This observation might help to settle the problem whether laminar shearing is an important factor of homogenization. It appears that good homogenization is accompanied by turbulent flow rather than laminar flow.

On the factor of time, our results showed that by allowing the milk more time in the valve, on gain in efficiency was obtained unless the pressure was also increased. The shortest duration of treatment was just as efficient as the longest treatment. The time range studied was from 0.55×10^{-4} to 2.36×10^{-4} sec. We also noticed that increasing the length of the homogenizing passage (or the dimension of the valve opening in the direction of the flow) within the investigated range had a slightly unfavorable effect on the efficiency of a valve.

In our earlier work, we used round orifices of various sizes. We observed that smaller holes were more efficient, though other factors such as the degree of turbulence, the duration of treatment, and the applied pressure were the same. In order to investigate more fully this dimensional effect, a number of rectangular orifices having the same cross-sectional area but varying in the breadth to width ratio were constructed and tested for homogenization efficiency. By so doing, it was possible to separate the effect of the cross-sectional area from the effect of hydraulic radius (cross-sectional area divided by wetted perimeter) of an orifice. These rectangular orifices, although having the same

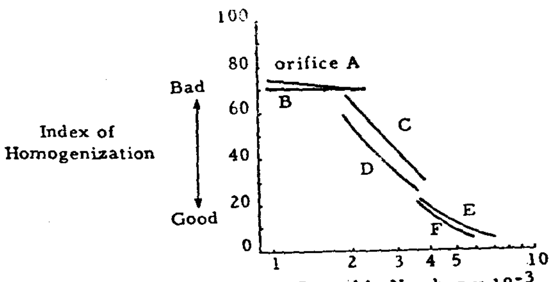

Fig 1. Efficiency of homogenization versus Reynolds number

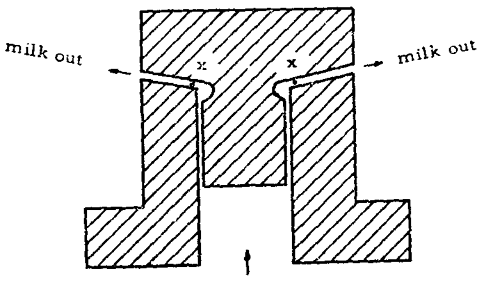

Fig 2. Outline of a poppet-type homogenizer valve

cross-sectional area and practically the same pressure-to-capacity relationship, exhibited distinct differences in their efficiencies. The efficiency of the orifice increased as the hydraulic radius was decreased. This means that a high ratio of wetted perimeter to cross-sectional area favors homogenization action.

The next factor influencing the efficiency of a homogenizer valve to be discussed is the back pressure on a homogenizer valve. It was reported previously (3) that actual sampling of milk at different radial positions in a poppettype valve showed that homogenization action should take place at a point inside the valve opening at a very short distance from the entrance to the opening. This location is illustrated by point X in the diagram of a common homogenizer valve in Fig. 2. Therefore, to study the effect of back pressure, valves that resembled the poppet-type valve, but had their seats narrowed down to substantially nothing so that the back pressure on the homogenizing region could be easily measured, were used. The results showed that a back pressure of 50 to 150 psi increaased the efficiency of a valve. Fig. 3 shows a few representative curves of the relationship between back pressure and value efficiency.

In a common poppet-type valve which has a relatively wider seat, the back pressure on the homogenizing region could be expected to be quite high because of the high frictional resistance beyond the homogenizing region. On the graph shown in Fig. 3, the operation of such a valve would be represented by a point at a considerable distance to the right of the optimum back pressure.

A homogenizer valve, shown in Fig. 4, was built to demonstrate the results of the present investigation. Its openings are rigidly fixed by spacers to obtain a hydraulic radius of less than 0.0005 in. The surfaces forming the homogenizing passage are about 0.01 in wide. The entrance to this passage is formed by corners of acute angles. Only 800 psi pressure is necessary for it to homogenize fresh whole milk as satisfactorily as conventional-type valves operating at 2000 to 3000 psi pressure. Of course the capacity and operational pressure of such a valve is fixed for a certain given product. Its clearances could only be adjusted to a limited extent without impairing its efficiency by changing the spacers. Two likely limitations of this valve may arise from the erosion of the valve and clumping of fat globules in high fat products. Investigations in these respects had been undertaken, although no such difficulties had been experienced to date.

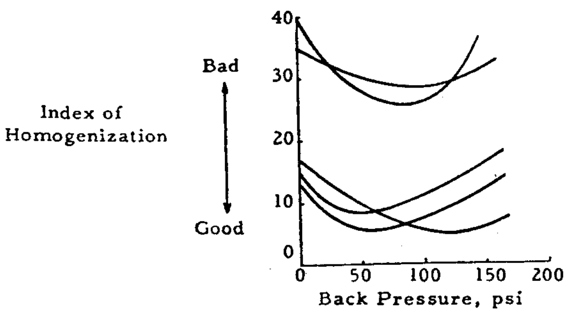

Fig 3. Efficiency versus back pressure of a sharp-edged homogenizer valve

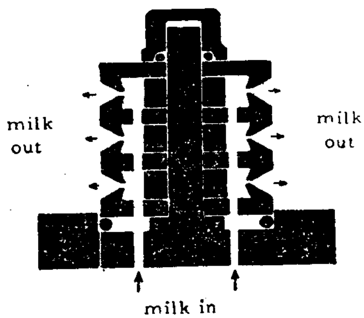

Fig 4. Outline of a multiopening sharp-edged homogenizer valve

SUMMARY

1. The homogenization efficiency of a valve begins to increase with the Reynolds number only when the latter is over 2000.

2. A longer time spent by the milk in a homogenizer valve does not seem to increase the efficiency of valve.

3. Smaller hydraulic radius of the homogenizing opening produces better homogenization.

4. A back pressure of 50 to 150 psi applied to the homogenizing region is most desirable.

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