Membrane press filtration is a semi-continuous process. The process can be divided into two sequences: filtration and squeezing (figure 3). On filling the filter, the slurry is pressed into the filter chambers, which allows a large part of the free olein to be separated from the slurry. In the second step, the concentrated crystals are mechanically squeezed between the membranes in order to extract part of the olein which is retained inside the solid mass. Thereafter the filter is opened and the cakes are discharged by gravitation.
Due to the higher differential pressures applied (4-8 bars in the case of a standard membrane press filter), the separation of the solid from the liquid fraction is less sensitive to changes in crystal structure and morphology.

Comparison vacuum versus press filtration
Compared to vacuum filtration, membrane press filtration clearly presents some important advantages: higher separation efficiency, higher tolerance to crystal morphology changes, better protection against oxidation, faster filtration and much lower energy consumption. Due to the improved separation, the stearin is characterized by a lower IV, a higher melting point as well as a steeper solid fat curve (SFC). The olein, on the other hand, is of at least the same and in most cases of a better quality which is for example expressed in a better cold stability and a slightly higher iodine value. This is a consequence of the fact that the olein fraction, released during squeezing, largely originates from the entrained liquid fraction: due to the very close contact between the entrapped olein and the crystal surface, exchange of material between liquid and crystal surface is more intense which results in a lower concentration of the higher melting triglycerides in the entrapped liquid fraction as compared to the free bulk olein phase.

Olein entrainment in stearin
Removal of liquid from the solid phase is more efficient in a membrane press filter than in a vacuum filter. This is mainly due to the larger differential pressure applied. With a standard membrane press filter operating at 4 to 8 bar pressure, the olein yield in the case of palm oil easily increases with 10% (calculated on the olein fraction) and even more as compared to vacuum filtration. An example is given in table 5.
The separation efficiency of a filter press cannot be correlated as such to the differential pressure applied. The conditions under which the oil is crystallized as well as the filtration conditions largely determine the residual olein content in a stearin cake. Large differences are also observed between fatty matters of different origins (table 6).
Reduction of olein entrainment cannot only be solved by increasing the squeezing pressure. More important are the conditions of crystallization: especially the crystal morphology largely determines the degree of olein entrainment and hence separation efficiency.

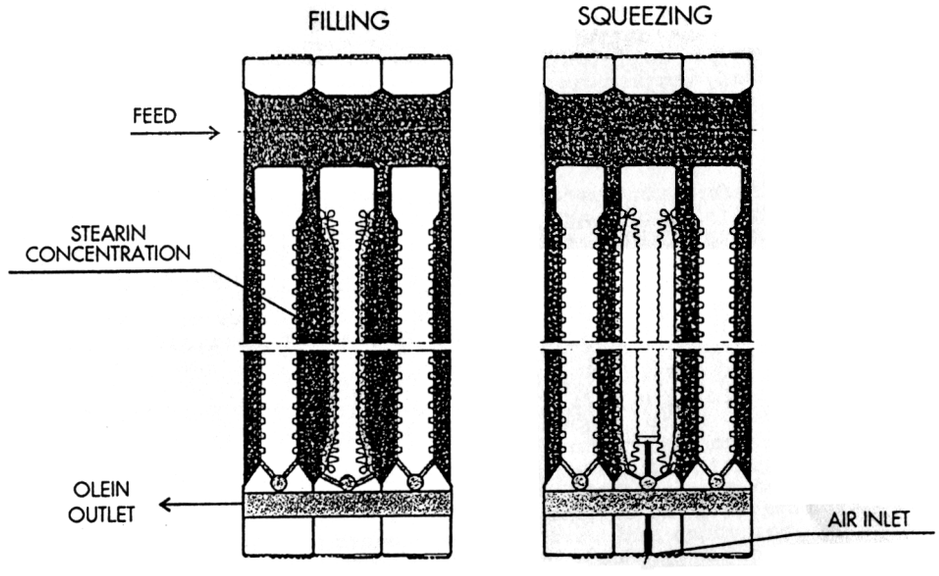


Figure 3a: Filtration sequences in membrane press filter plate

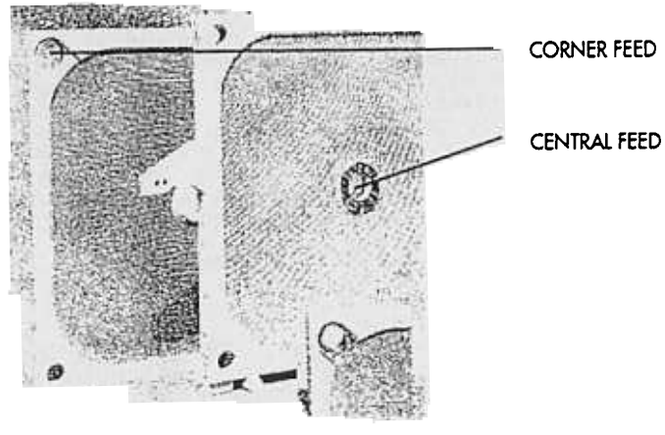


Figure 3b: membrane filter plates types with corner and central feeding

Table 5: Comparison of vacuum versus membrane press filtration in a palm oil fractionation

filtration data	vacuum filtration	press filtration
IV palm oil	52	
IV olein	57	57
IV stearin	40	34
SFC slurry	12 %	12 %
SFC cake	41 % <——————>	55 %
Yield olein	71 % <——————>	78 %

IV: iodine value; SFC: Solid fat content

Table 6: Olein entraimnent in stearin cake of different fatty matters (standard 6 bar membrane filter)

Origin of Fatty matter		Solid fat content (SFC) slurry %	cake %	Olein entrainment %
Palm oil		14	58	42
IV 52		20	55	45
		29	51	49
crystallization	1	18	42	58
procedure	2	17	53	47
filtration	*fast*	22	46	54
procedure	*slow*	22	51	49
Palm mid fraction		15	73	27
IV 49		24	61	39
		31	55	45
Soy bean oil		31	64	31
hydrogenated IV 75		33	74	26
Milk fat		11	54	46
		16	42	58
Tallow		13	44	56
Lard		12	41	59
Fatty acids		28	69	31
Fatty acid esters		30	80	20
Mono/di/triglyc. mixture		9	31	69

As a rule, it can be stated that crystals which are uniform in size and which are firm, improve the separation efficiency. This requests crystallization conditions which favour a narrow crystal size distribution and which allow a high density of the crystal packing with minimum inclusion of liquid inside the crystal matrix.

Technical developments

Nearly all industrial dry fractionation systems in operation today, are semi-continuous systems. Among them the De Smet and Tirtiaux systems are best known. Although the different fractionation systems are based on the same principles, they reveal differences with respect to their technical approach.
In figure 4, a typical diagram of a dry fractionation system is presented. Before crystallization, the oil is melted in order to fully destroy crystal memory. It is then pumped into a crystallizer, where it is cooled according to the programmed cooling profile. Subsequently, the crystallized oil is sent batchwise to the filter.

Crystallizer
The crystallizer design determines the conditions under which the oil crystallization process is controlled. Especially the rate with which crystallization can take place in the melt, is largely determined by the technical features of the equipment, more specifically the heat exchange properties of the crystallizer vessel. Crystallization can be conducted in several manners. The oil is normally cooled by following a predetermined cooling water temperature profile or according to a differential temperature profile between the oil and the cooling water circulating in the double jackets and/or cooling coils (figure 5). Which of these approaches gives the best results with respect to the quality of the end products is difficult to define since both approaches already have proven their efficiency.
There are different industrial crystallizers which operate in a different manner (figure 6). Some of these allow the crystallization process to be executed in a relatively short time (e.g. De Smet crystallizers), whereas other systems imply much longer cooling times (e.g. Tirtiaux). This difference in crystallization time is a consequence of the technical concept of the crystallizer rather than of the process consideration.

Filter
The membrane press filter is by far the most preferred filtration technique in dry fractionation. The standard membrane press filters normally operate at maximum pressures of4 to 8 bars, which is in most cases more than sufficient. All membrane press filters operate in a similar way but they may show distinct technical differences: there are for example top bar and side bar filters with a central or a corner feed of the filter plates (figure 2 and 3). Which design is most suitable depends largely on technical features as for example filter capacity, available space...etc.

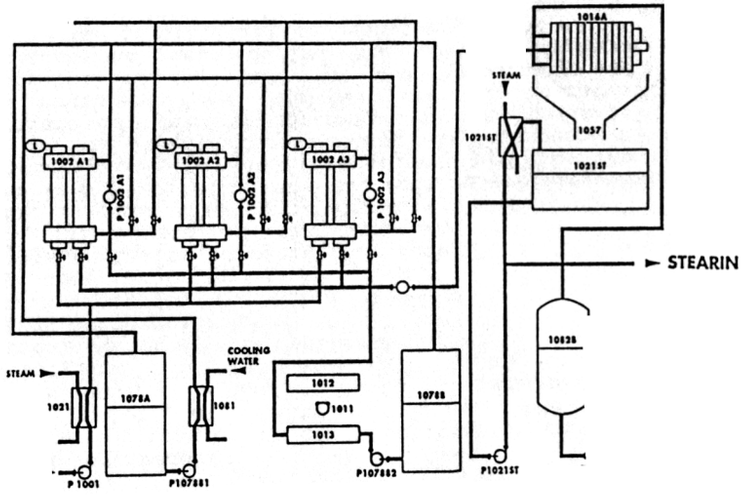


Figure 4: Flow sheet of a dry fractionation unit (De Smet)

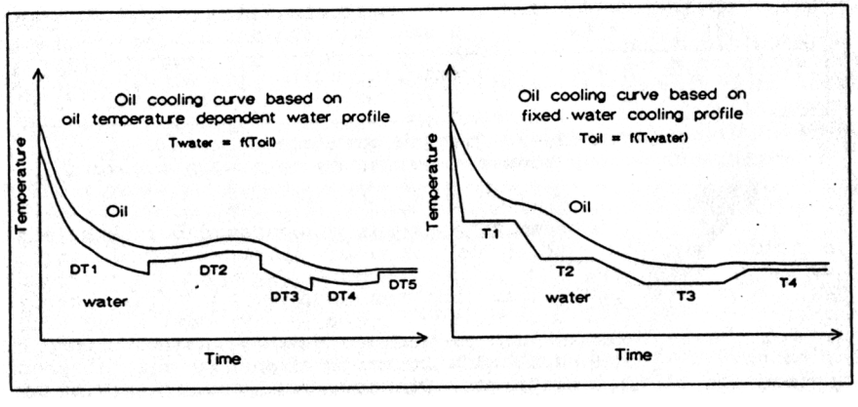


Figure 5: Schematical representation o nperature
related and independent water cooling

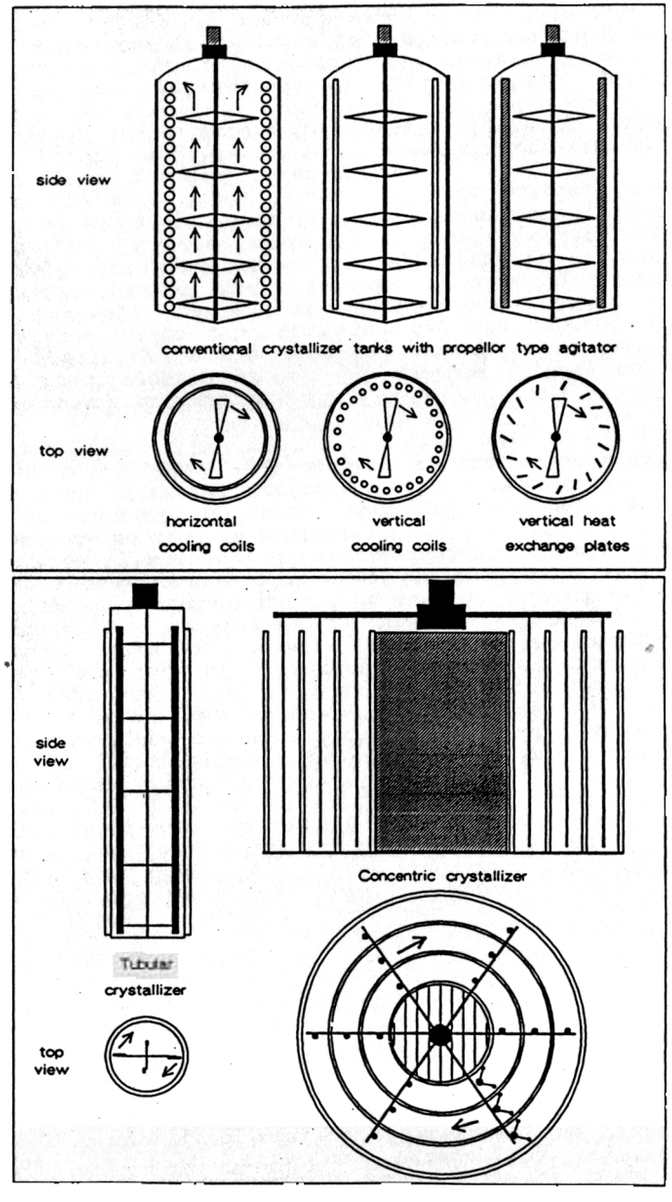


Figure 6: Schematical representation of most common typ
crystallizer vessels applied in dry

High pressure filter
Today, new high pressure membrane press filters are being developed to operate at pressures up to 50 bar. Especially in the production of speciality fats as for example the cocoa butter replacement fats, higher pressures are necessary to meet the required specifications.
Especially in the case where the solid fraction is the premium product, the advantage of using high pressures is reflected in a lower residual olein content of the stearin cake. This in turn has a positive effect on the stearin quality i.e. a lower iodine value, a higher melting point and a steeper SFC profile. In table 7, a comparison of a 6 bar versus a 20 bar filter press is given in order to demonstrate the impact of the squeezing pressure on the stearin quality.

Table 7: Effect of squeezing pressure on the separation efficiency and quality of fractions

Refractionation Palm olein IV 56	6 bar olein	6 bar mid fraction	20 bar olein	20 bar mid fraction
IV	64.5	49.0	64.4	44.5
CP (°C)	1.9		2.0	
MP (°C)		29.8		30.9
yield (%)	45	55	58	42
SFC cake		53.5		66.5
SFC 10°C		67		78
(%) 20°C		34.5		51
30°C		0.3		2.2

CP: cloud point; MP: melting point; IV: iodine value
SFC: solid fat content

Technical requirements
Due to the application of dry fractionation on a continuously growing number of fatty products, the fractionation installations now in use are being further developed in order to satisfy the highest demands with respect to flexibility in operation, versality in application as well as profitability in energy consumption.
The main features to which a fractionation plant should comply, are:
1. High flexibility in operation. Each oil is characterized by its typical crystallization behaviour and hence requires a specific thermal treatment. Principally, the crystallization process is controlled by the oil cooling profile which in turn is a function of the water temperature profile. The rate with which the oil temperature responds to changes in the water temperature is strongly determined by the technical features of the equipment. Both the heat transfer characteristics in the crystallizer as well as the homogeneity of the oil temperature and mass during the cooling sequence, largely determine the crystallization behaviour of the oil.
2. Reproducibility of the process. This implies both the quality of the finished products as well as the capacity of the plant. Due to seasonal variations or different pretreatments, oils and fats can show considerable variations in their chemical composition as well as in their physical behaviour. This in turn may affect the crystallization behaviour during fractionation. Therefore, the fractionation process must be easily adaptable in order to overcome such variations.
3. High freedom in cooling profile design. Some oils require a special treatment in order to obtain the proper crystal form and morphology. The equipment should therefore be adapted to the crystallization process and not vice versa
4. Solid mechanical construction which allows to work even under extreme conditions. The crystallizer and especially the agitator must be able to withstand high viscosities. During crystallization, viscosity increases as a result of the increasing solid fat content and the interactions between the crystals. The viscosity is an important parameter as it influences the homogeneity of t he oil mass and hence heat transfer during crystallization. In some cases, the viscosity can reach very high values (> 5000 mPas), which can lead to high mechanical stress.
5. Constant homogeneity during crystallization. A crystallizer should be designed to avoid formation of static zones as well as settling of crystals on the cooling surface.
6. Easy feed stock change. This should not only be the case when oils and fats of different origin are fractionated but also when olein or stearin fractions are submitted to refractionation. Cleaning of the crystallization as well as of the filtration equipment should be easy and efficient.
7. Fully automated operation. Most of the installations today are operated by means of a central computer, excluding manual interventions as much as possible.
8. Low maintenance and energy consumption as well as miminum waste. Both direclty reflect the profitability of the fractionation process with respect to the other modification processes.

Multi purpose fractionation unit
The dry fractionation process is applied already on a large scale, especially in the palm oil processing industry where installations up to 2000 tons per day are running non-stop. Today, however, beside the traditional large capacity fractionation plants, there is more and more demand for small processing units with rather low capacities (2 -> 100tpd), to be used on a whole variety of very specific products. Flexibility and adaptability become more and more important as products are more often fractionated in multiple stages in order to obtain the desired products.
Another point of interest in today's requirements of a fractionation installation, is the simplicity of installation and ease of upgrading.
Today, a new generation of fractionation plants are commercialized: as a response to today's fast changing demands, skid mounted fractionation plants are being developed in order to satisfy all requirements.
In figure 7, a computerized three dimensional view on such a skid mounted fractionation installation is represented.

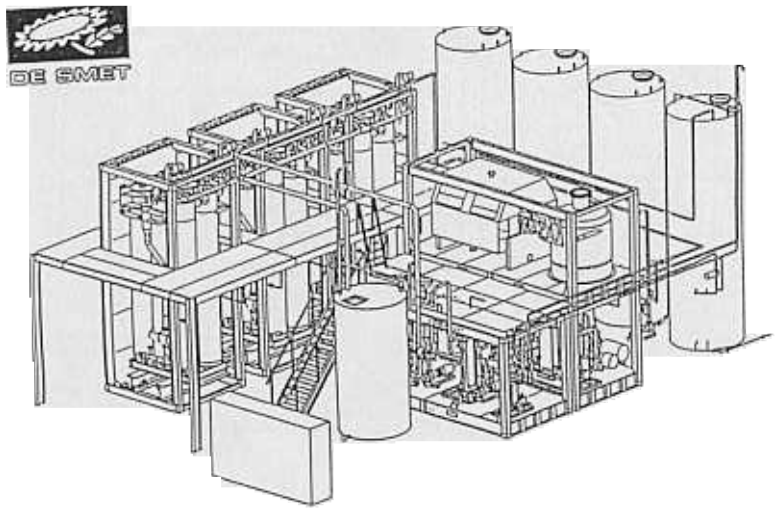


Figure 7: Computerized threedimensional representation of a skid mounted fractionation unit

The plant is a 50tpd unit expandable to 100tpd. The system has been developed to simplify as much as possible the construction and installation together with retainment of maximum flexibility in operation and application. Another benefit of a skid mounted unit is the fact that building costs are minimized: a concrete floor and roof are already sufficient. Rearrangement of the unit or enlarging of the capacity only takes minimum time.
A great deal of the improvement of the fractionation technology is due to a continuous evolution of both hardware systems (e.g. programmable logic controllers PLC) and user friendly computer software packages. Today's fractionation units are designed to operate fully automatically with minimum human intervention and maximum security.

Scientific approach

The increasing applicability of dry fractionation on a continuously growing number of different oils, has also increased the interest and need for clarification of this process. Although much work has already been done in this field during the past 20 years, fractionating oils and fats is still considered more as an art than as a science.
Due to the large differences in composition between the different natural oils and fats, each oil is characterized by its typical physico-chemical behaviour and hence requires specific fractionation conditions. In most industrial fractionation plants which are operational today, however, the

setting and optimization of these process conditions is still a matter of long experience and trial and error.
In order to simplify the construction of a proper cooling profile and to optimize the separation conditions, valuable information can be obtained from a whole variety of interesting analytical techniques.
An example of such a more scientific approach on a milk fat fractionation is given below. The same approach, however, can also apply to on other types of oils and fats.

Milk fat fractionation
In order to preset a cooling curve for a given oil, it is of importance to define the physical properties of the oil or fat one wishes to fractionate. A whole variety of methods of analysis are used to define the physico-chemical properties of a fatty matter. In table 8, some physical parameters of a given sample of milk fat are given.

Table 8: Physico-chemical characteristics of a given sample of Anhydrous Milk Fat

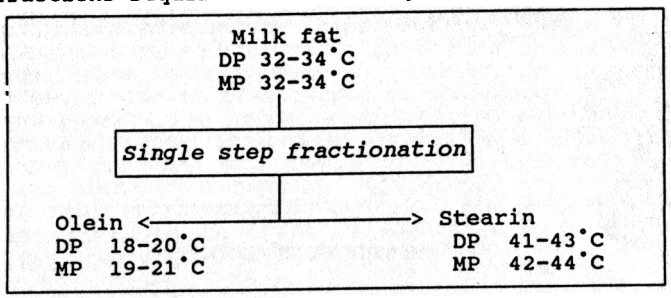
Milk fat	
DP: 32.5°C	SFC: 0°C: 52.6%
MP: 34.0°C	5°C: 49.9%
CP: 17.2°C	10°C: 41.6%
IV: 38.5	15°C: 28.7%
	20°C: 13.2%
	25°C: 7.5%
	30°C: 4.7%
	35°C: 2.4%
	40°C: 0.0%

DP: dropping point; MP: melting point
CP: cloud point; IV: iodine value
SFC: solid fat content

Such information already gives you a good idea of the temperature range in which crystallization occurs. The conditions under which fractionation must be performed, however, do not only depend on the physical properties of the initial phase but are also largely dependent on the technical features of the crystallizer vessel: according to the type of crystallizer, cooling can only take place slowly or crystallization may occur faster. Furthemore, the physical characteristics of the final products also affect the cooling curve. In table 9, some specifications of a liquid olein and solid stearin fraction of a milk fat are given as an example.

In figure 8, a typical cooling profile of a milk fat in a De Smet fractionation unit is given. In order to quantify the oil crystallization course during cooling, samples are taken at regular time intervals from the crystalliser: the solid fat content of the slurry (SFC) as well as the viscosity are measured immediately after sampling. From the SFC data, the start of crystallization or initiation as well the crystal

Table 9: Product specification of the olein and stearin fractions required after a single fractionation step



growth can be followed very accurately. A good estimation of the start of crystallization can also be obtained from the increase in temperature of the oil: this increase in temperature is a consequence of heat release during crystallization at a low degree of undercooling (T_{oil}-T_{water}). As crystallization proceeds, the viscosity increases gradually. The viscosity is an important parameter, as it influences the homogeneity of the slurry and hence the heat transfer during crystallization.

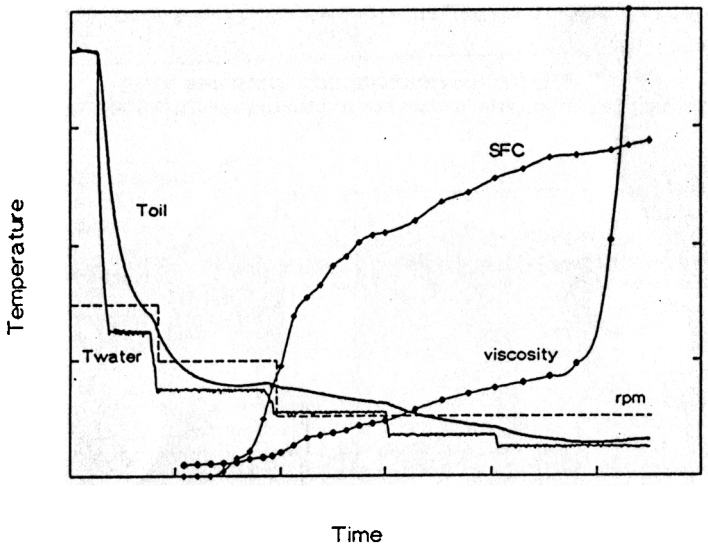


Figure 8: Cooling profile and crystallization behaviour of a milk fat during controlled crystallization

The efficiency of fractionation is not only determined by the crystallization behaviour during the cooling sequence, but also by the separation conditions during filtration. The viscosity in particular can play an important role in filtration. This can be seen in figure 9: at different moments during crystallization, a vacuum filtration test is performed. From the data, several interesting relations can be deduced. The yield in olein decreases with increasing SFC, which is evident. On the other hand, the SFC of the stearin cake, left behind on the filter cloth at the end of filtration, increases, indicating improved de-oiling. The filtration rate, expressed in kg of olein filtered per square meter and per hour, is characterized by two steep drops: a first in the initial phase, and a second at the end. The first is due to an increase in SFC, while the second is a result of a sudden increase in viscosity. The latter phenomenon is a consequence of a second crystallization: beside the spherical crystalline entities, small needle-like crystals may appear in the remaining oil phase, to form a sticky network between the crystals. The appearance of the second crystallization can also be observed in the oil temperature curve (figure 8) in the form of a second increase in oil temperature.

In figure 10, the course of filtration during different membrane press filtrations, is represented. The filtration curves can be divided into two steps: the filling and the squeezing steps. On filling the filter, a large part of the free olein already separates from the slurry. In the second

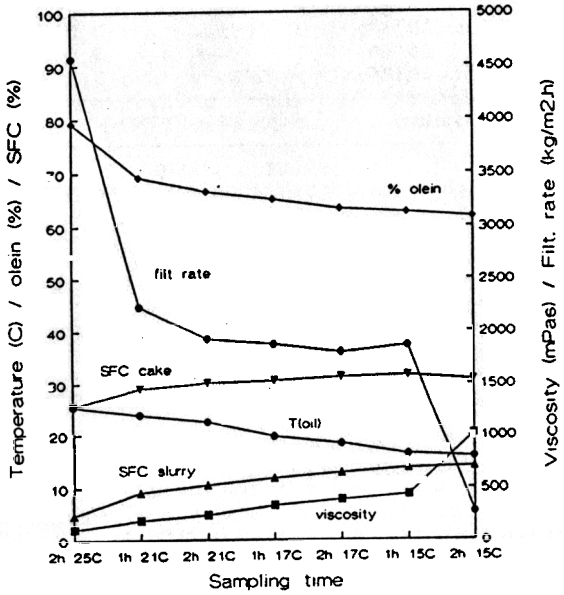


Figure 9: Vacuum filtration results of milk fat obtained during different stages of crystallization