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MODERN METHODS OF SEPARATION THE COMPONENTS OF WHEAT

Abstract

The isolation of starch and gluten out of wheat requires sophisticated techniques. In the past it was mainly hand operated. Two methods: Martin process and Hydrocyclone process, as well as the advantages and disadvantages of them are described.

The modern methods of separation the components of wheat involve a three phase separator and/or decanter or the combination of the traditional and novel methods. The usage of three phase separators and decanters gives a lot of advantages to improve the wheat starch and gluten processing. It is possible to adjust the process to different raw materials and to optimise the yield of products and by-products, as well as reducing the quantity of effluent per ton of flour.

Introduction

The extraction of starch from renewable raw materials such as corn, manioc, potato, tapioca, wheat and others are accomplished by releasing starch granules from cell walls of plants and extraction. Different techniques are adapted to the specific raw material such as wet milling and dry milling. The separation procedures of foreign matters, such as fibres, proteins, fats and other non-starch components, as well as washing of the starch, are of particular importance.

Starch is used in the food and non food industry. For the food industry the starch is mainly converted into different kinds of glucose syrups. Besides native starch, after chemical and/or physical modification the starch is used in the non food industry.

General aspects of wheat starch production

The world starch production is about 46 mio. tons. Eighty-one per cent is produced out of corn and 8% from wheat.

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Especially in Europe the wheat starch production is of importance. From the total starch production of 8,2 mio. tons per year, about 30% is expected to be wheat starch.

During the last 20 years the wheat starch became more and more of importance and the wheat starch production increased more than 2500%.

The most important by-product of wheat starch production is wheat gluten.

Comparison of the composition of different raw materials

One of the important differences between the various raw materials is the starch content. Potato contains most of starch compared to corn and wheat. This based on the dry matter. Only the wheat flour has a higher potential of recoverable starch, but during the milling some starches are lost into the fibres (Fig. 1).

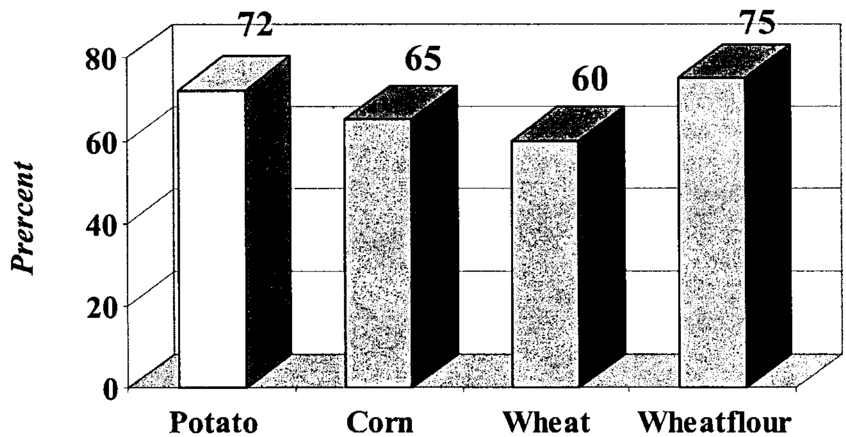

Fig. 1. Starch content on dry substance in relationship to different raw materials.

The comparison of the main components of corn and wheat (Fig. 2) shows that the endosperm in both raw materials is equal. The main difference is the content of germs and of the aleurone layer. Wheat contains a less amount of germs and a higher amount of aleurone layer and fibre.

The processing of a starch containing raw material will not only result in the starch, but also in a by product. The potato will give the lowest amount of by products based on dry matter, but contains approx. 75% water. This is a very big disadvantage.

Production of starch out of wheat will give the highest amount of by-products and the lowest amount of starch. With approx. 9,2% wheat gluten has a higher value than starch and other by-products (Fig. 3).

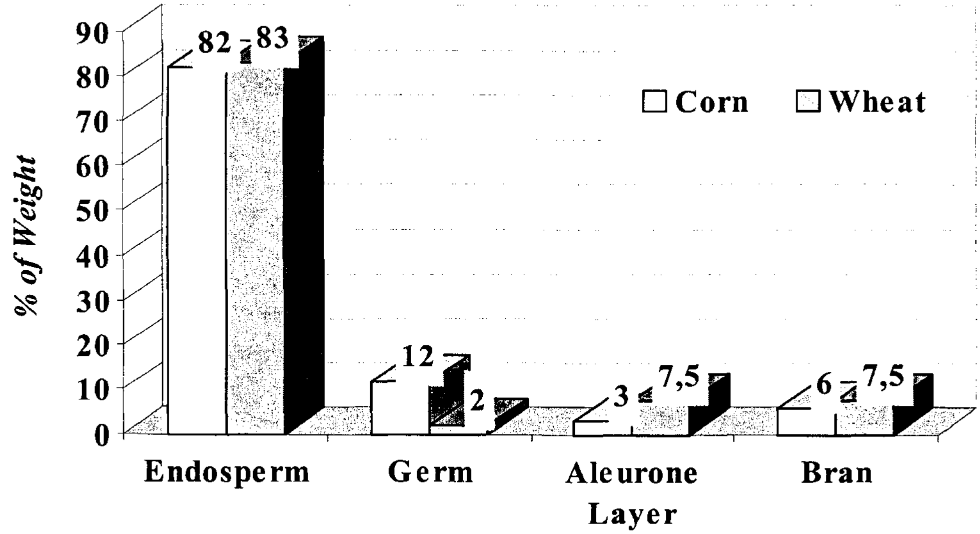

Fig. 2. Composition of the morphologic structure of wheat and corn.

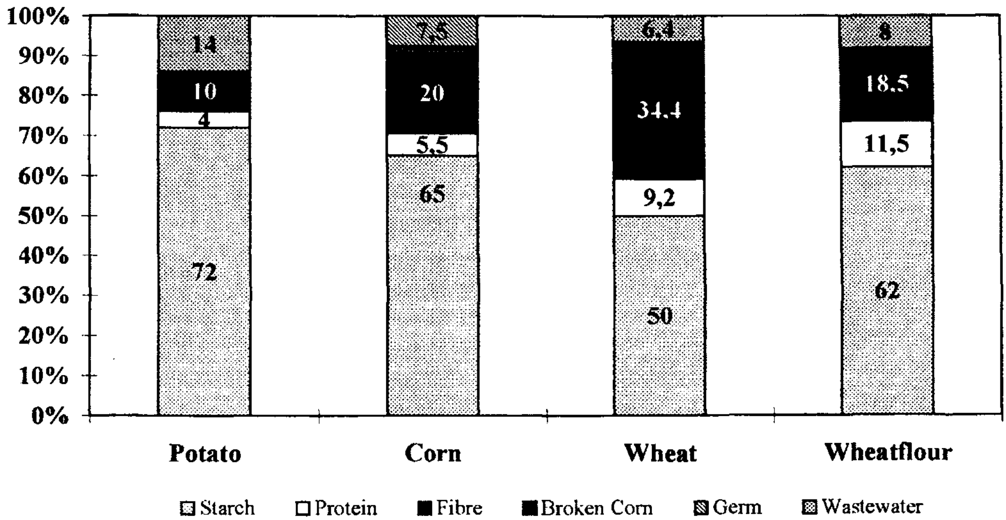

Fig. 3. Contents of starch and by products for different raw materials.

Using wheat flour, the starch yield will increase to a level of approx. 62%, the gluten yield to 11,5%, whereas the fibre, C-starch and B-starch as a by-product decrease to 18,5 %. The increase of the higher value main product resulted from the by product fibre of the flour mill. It is not possible to process wheat directly to wheat starch and wheat gluten without getting a native high value wheat gluten.

Comparison of the different methods for starch processing

The most important difference in the processing of corn, potato and wheat is as follows:

a) corn has to be wet milled,
b) wheat has to be dry milled,
c) potato and tapioca are rasped because of the high water content.

Corn has a horny endosperm. The protein matrix must be softened before wet milling and the protein does not form a viscoelastic mass. Starch has only one starch spectrum that means that corn starch is one modular.

In comparison to corn, wheat protein forms a viscoelastic mass – the so called gluten. The dry milling before starch recovery is necessary, to be able to recover the high added value wheat gluten. Out of wheat two starch fractions are obtained – the A-starch and the B-starch. A third starch fraction is present – the so called C-starch. This contains the hemicellulose and pentosanes. In a spin test in lab the b- and C-starch will be one fraction.

A unique characteristic of wheat starch granules is the bi-modularity of its mass distribution, that does mean that starch of wheat consist out of 2 main size-populations of starch granules (Fig. 4).

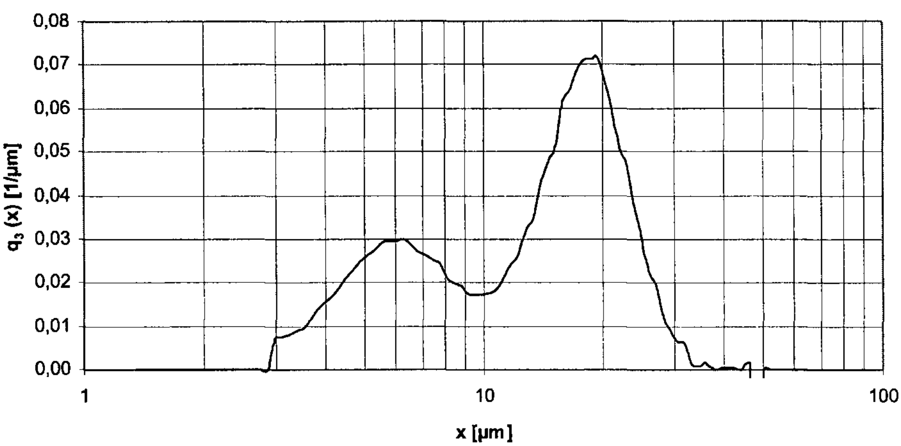

Fig. 4. Massdistribution of a wheat starch depending on its particle size.

The unique characteristics of wheat are leading to a sophisticated technique to isolate starch and gluten out of wheat flour. Two special features are the preconditions for the application of processing techniques. Firstly the ability of parts of its protein fractions to swell up with water and form, under influence of mechanical energy input, a cohesive viso-elastic mass termed gluten and, secondly, the characteristic presence of two fractions of starch granules which differ considerably from another in size and shape.

Due to these reasons the technical solution to recover starch and gluten from flour is much more complicated than from corn and potato.

Besides that another important point is that wheat and wheat flour contain a relative high amount of hemicellulose and pentosanes. These fractions do have viscous behaviour. During processing wheat flour to starch and gluten will influence the recovery of starch, in particular the small granule starches.

Starch processing out of wheat flour

Starch processing out of wheat flour is a several hundred years old technique. In the past it was mainly hand operated. One of this process was the so called Martin process.

It is very important to mill wheat to wheat flour, before processing it to starch and gluten, in order to obtain the wheat protein as native wheat gluten.

Martin process

The characteristics of the Martin process to recover starch and gluten out of wheat flour is, that a wheat flour is mixed with water in a ratio of 1:0,6. In a mixer the flour and water are kneaded to a stiff dough. After this procedure the dough is washed with a high amount of fresh and process water in a special starch and gluten separator. This washer, a so called extractor, has several sections. At the bottom of these sections screens are located, where the starch milk passes through. The dough is moved from section to section by a shaft assembled with paddles. Fresh water is used in the last section of the extractor to wash the gluten. Wash water that passed through the screens is used in counter current in the section before. Crude starch milk is leaving the washer from the two first sections with a concentration of approx. 8 ° Be.

The so extracted suspension contains all components of the flour besides the extracted wet gluten. In consequence the crude starch milk contains the total recoverable starch, the A- and B-starch, the Hemicellulose and the (soluble and insoluble) Pentosanes, the Solubles together with the Proteins and nonstarch Carbohydrates.

The difference in the apparent density of wheat components can be utilised to partially separate the dough into its fractions by means of centrifugal forces. When such a separation is carried out in a centrifuge beaker, two to four, clearly separable layers are formed. Figure 5 gives an overview about a spin test of a crude starch milk from potato, corn and wheat starch. The heavy fraction stands for the separable starch of each raw material. The medium fraction contains the corn gluten, the fine fibre and ore the C-starch. The light fraction contains the water, the soluble solids and the very light suspended solids.

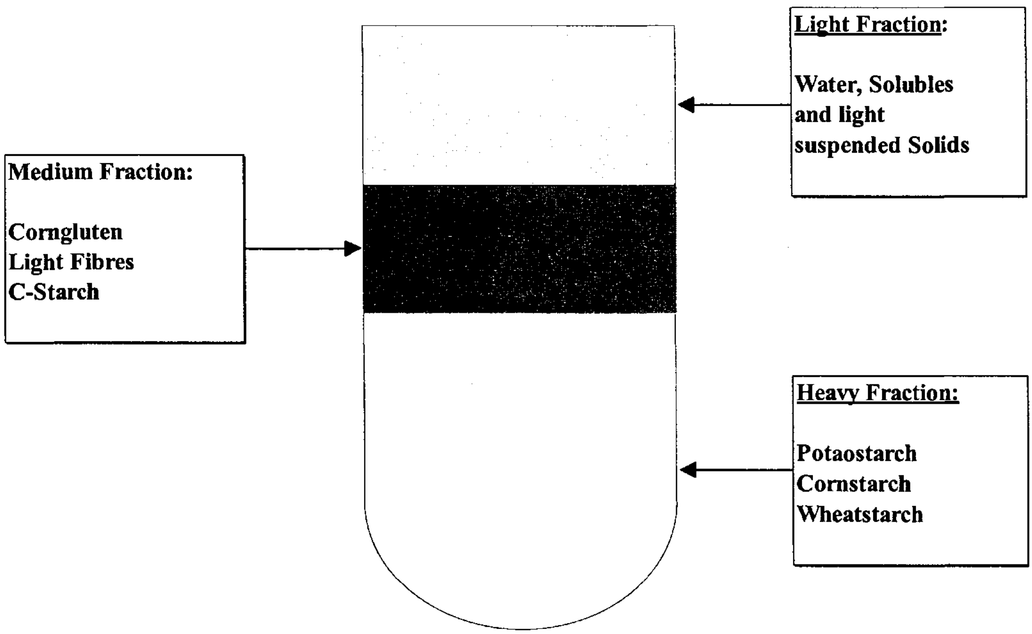

Fig. 5. Overview about a spin test of different crude starch milks.

The task of separation and washing of starch milk is to achieve the purified starch and to separate the fibres, proteins, fats, soluble like nonstarch carbohydrates, sugars, protein, fats and minerals from the starch.

This aim seems to be relatively difficult for the Martin process, because of the vast mixture of suspended components in the crude starch milk. Due to the presence of the pentosanes, which influence the behaviour and the agglomeration of the wheat gluten, much more water is needed for diluting the pentosanes. That is one reason for the high fresh water consumption by using that separation technique. The second explanation for a higher fresh water consumption, is the necessity to reduce the soluble protein content in the final starch. This value has to be reduced down to 50 mg/100 g starch.

Hydrocyclone and other processes

Another method to isolate starch and gluten out of wheat flour is the so called Hydrocyclone process.

In this process diagram a hydrocyclone system find its application after the dough preparation. The heavy A-starch is separated and leaves the hydrocyclone unit with the underflow. The overflow contains the wet wheat gluten, the B-starch, C-starch, like hemicellulose and pentosanes, and the soluble solids, like proteins, fats, sugars, etc. vall together.

The disadvantage of this process is similar to the Martin-process, that the gluten cannot be isolated directly from hemicellulose and pentosanes. On account of that gluten can be found together with these components in the overflow of the hydrocyclone system. The presence of the pentosanes will also influence the behaviour and the agglomeration of the gluten. That does mean that more fresh water for diluting this components will be necessary.

Westfalia separator 3-phase-decanter process

Westfalia Separator developed the three phase decanter process. This process was installed in three German wheat starch factories in 1984 at the same time.

In the years before 1984 have been performed various trials to separate, after using a homogeniser in order to agglomerate the wheat gluten, a wheat-flour-water-slurry with a decanter. Anyhow at that time it was not possible to achieve a good separating efficiency.

Flour milling

The Westfalia Separator decanter process also requires wheat flour for the separation of starch and gluten.

World-wide there do exist different possibilities to produce flour out of wheat. One way is to consume standard bakery flours, extracted with a normal mill design. The flour can be extracted by a normal mill in purpose to produce bakery flour. Sometimes a so called short flour mill is used. In this design less roller mill stages are included. Another possibility is to use a normal hammer mill, for example a so called ultra rotor.

A typical analysis of a wheat flour is listed according to Table 1.

Besides these normal characteristics, it is very important, that the used flour has a good gluten agglomeration. Only under these circumstances it is possible to achieve a high gluten recovery and fewer losses of gluten proteins within the different starch fractions.

Table 1

Typical analysis of a wheat flour for starch processing.

Water	approx.	14,50
Protein (N x 5,7)		11,50
Ash		0,63
Fat		1,50
Crude Fibre		1,50
Starch		80,00
(all Numbers are based on Dry Matter)		
Wet Gluten		28,00
Amylogram		500 BU
Falling number		250,00

Slurry preparation

The wheat flour before processing it in the wet starch process should have a relative short resting time in the flour storage silos. The storage time should not exceed more than 72 hours.

During this time the flour passes its maturation in outdoor flour silos. From there it is conveyed into a small bin in front of the flour dosing system. The dosing system can be a weigh belt feeder or a loss and weight dosing system. It is from significant importance to realise a continuous and not fluctuating dosing of flour and water. The flour is fed directly from the weighing into the flour-water mixer. Together with the flour process- or fresh-water enters the mixer.

The optimum flour-water-ratio should be established with about approximately 1:0,85–0,95.

The task of the mixer is to hydrate all flour particles in order to have a slurry which is free of lumps.

The temperature of the slurry should be among 30 and 40 centigrade, to achieve the best gluten agglomeration (aggregation).

After the mixer the slurry enters a homogeniser. This homogeniser is well known in the milk industry because of its duty to homogenise the protein and fat in milk. Figure 6 shows a cross section of a homogenising valve.

The slurry is fed by an eccentric screw pump into the homogeniser. Pistons in the homogeniser are pumping the slurry through the homogenising valve. The slit distance of the valve is adjustable, so that the back pressure can be risen up to 100 bar. The pressure in the slurry increase than up to 100 bar and after the valve the pressure drops down to a normal pressure. Due to different kinds of stressing, like relaxation and the shear effect in the valve, the energy input is introduced into the protein matrix of the flour-water slurry and agglomerates the gluten proteins.

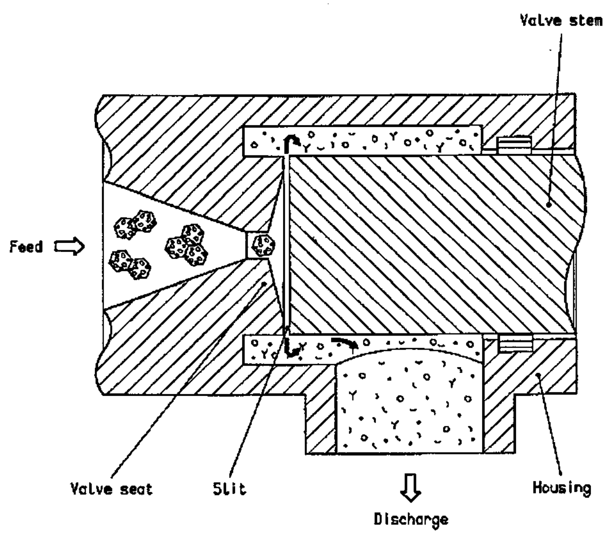

Fig. 6. Section of a homogenizing valve.

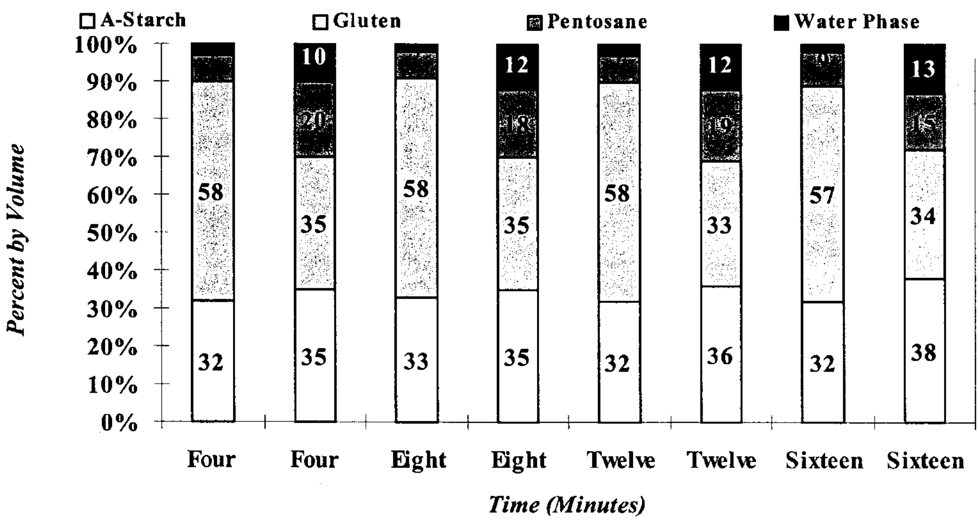

Fig. 7. Influence of the homogeniser on the gluten formation and separation efficiency.

To show the influence of the homogeniser on the gluten agglomeration and the separation of the components of a wheat flour, samples were taken in front of the homogeniser and direct after the homogeniser. After four, eight, twelve and sixteen minutes the slurry was centrifuged in a laboratory centrifuge. The percentage of volume of the different layers have been observed and the results are shown in Fig. 7.

It was evident that the separation effect of the components could be improved due to the homogeniser and that the best results have been achieved processing the combination of a homogeniser and a resting time of sixteen minutes. On the other hand it was obvious that a certain energy input was necessary to obtain a better gluten agglomeration, in order to improve the separation of wheat components. Without any extra energy input into the slurry and only a certain resting time it is not possible to achieve a good separation.

This is the reason, that in real processes the slurry has to be treated with a system to transform the right energy into the slurry and to install after the gluten agglomeration a resting tank to stabilise the protein matrix. One machine could be a homogeniser.

Separation the components of wheat

An eccentric screw pumps the slurry into a three phase decanter.

A decanter (Fig. 8) is a horizontal separator with an installed conveying screw. This scroll is operating with a differential speed to the revolutions of the bowl. The g-force is approx. 2500 to 3500 and the differential speed approx. 60 rpm.

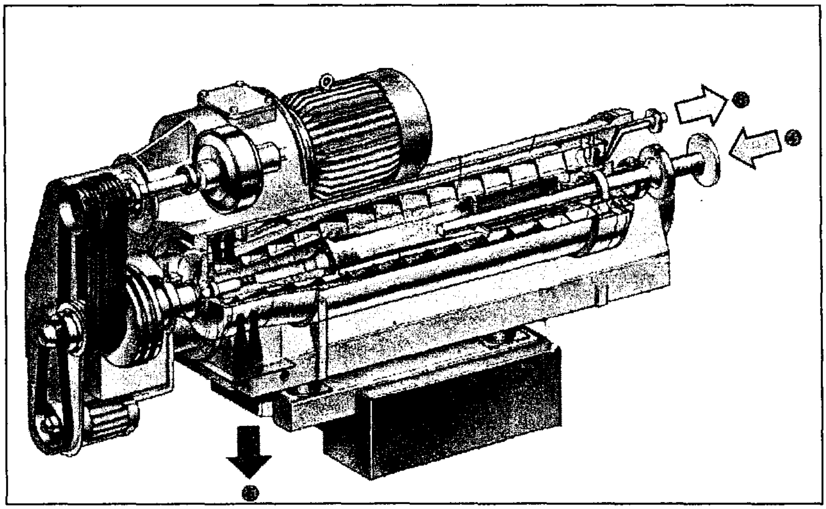

Fig. 8. Decanter type CA 505 with centripetal pump and 2-gear-drive.

Figure 9 shows a 3-phase-decanter type CA 755 with a 2-gear-drive and an installed centripetal pump.

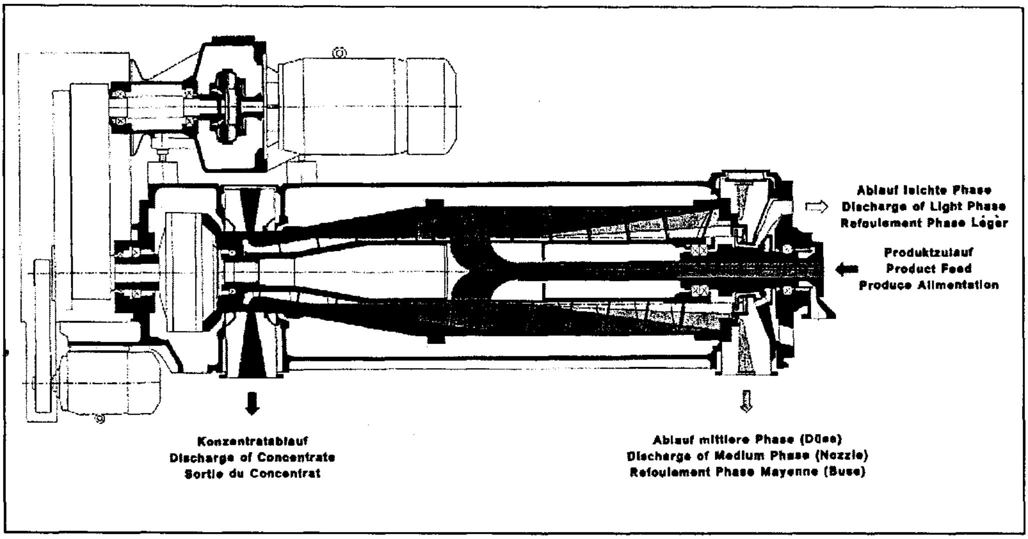

Fig. 9. 3-Phase decanter type CA 755 with 2-gear drive and installed centripetal pump.

This decanter is equipped with a 2-gear-drive. This 2-gear-drive was developed by Westfalia Separator and is patented at home and abroad. The 2-gear-drive allows the adjustment of the differential speed of the scroll depending on the torque developing at the motor. The torque depends on the infeed quantity, concentration and particular characteristics of the solids. The solids as particles with the highest density are separated and conveyed with the scroll at the discharge of the decanter.

The overflow of the decanter is leaving the machine by an installed centripetal pump. This installation is leading to two main advantages. On the one hand it will influence the processing of foamy products positively and on the other hand there is no need to install another pump after the decanter.

The difference of the 3-phase-decanter is based on the possibility to separate a third phase, the so called medium fraction. This fraction can be influenced in quantity, by mounting one or more nozzles, and qualitatively by changing the relative position of the nozzle.

In front of the decanter a further amount of fresh and/or process water for diluting the slurry is added. Normally this amount of water is about 0,3 to 0,9 m^3 per ton of flour. The temperature should be adjustable from 25 to 45 degrees centigrade.

When the slurry and the diluting water are fed into the decanter, the wheat components like the agglomerated gluten, the starch and the pentosanes, will be separated in the decanter bowl. Due to the centrifugal force the starch, because of its highest apparent density, is separated from the liquid phase and settles down on the inner surface of the bowl. The so separated starch will be carried out of the decanter by transferring it with the scroll towards the concentrate discharge.

The gluten and B-starch and pentosanes are leaving with the nozzles of the medium fraction. In the light fraction most of the pentosanes, which are representing the sticky carbohydrates of the wheat flour, and some very small size starch granules are leaving the decanter with the installed centripetal pump.

Figure 10 gives a good impression about a spin test of the different fractions of the 3-phase-decanter.

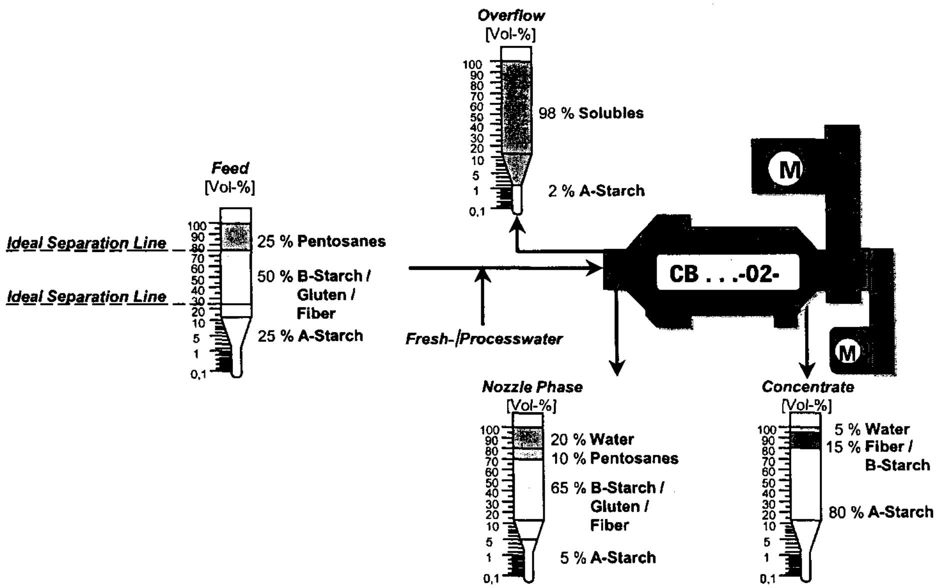

Fig. 10. Spin test of the different phases of 3- phase decanter.

It is of great significance, that pentosanes, as fraction of the lowest apparent density in the slurry, can be found mainly in the overflow of the 3-phase-decanter. This fraction is characterised with a remarkable rheologic property, because of its viscous behaviour.

One of the most important advantages of the three phase decanter process is, that this viscous mass is separated from the gluten in a very early stage of processing. That does mean that this pentosane fraction will not influence the gluten and the behaviour while separating the gluten and the B-starch.

Figure 11 shows the mass distribution of a wheat flour around a three-phase-decanter. On the discharge of the concentrate more than 85% of the A-starch leaves the decanter. Together with the gluten approx. 10% of the A-starch leaves through the nozzles of the decanter. This starch fraction contains mainly small granule starches with an amount of approx. 60% of starch granules smaller than 10 µm.

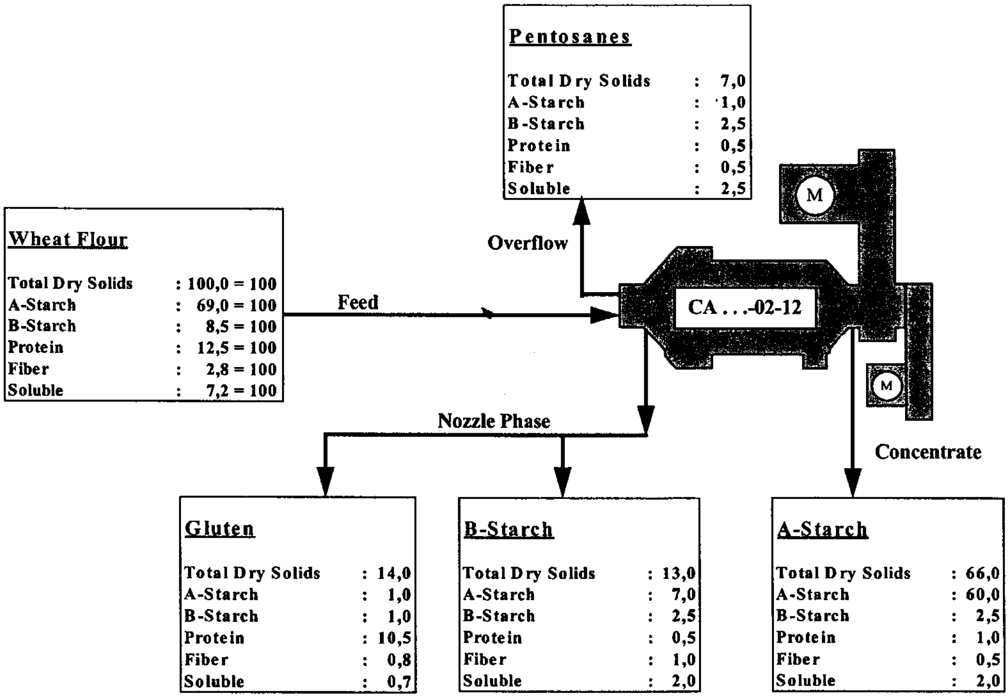

Fig. 11. Distribution of the wheat flour around the 3-phase decanter.

One important point can be seen from these numbers. The concentrate with the A-starch contains only 28% of the soluble solids of the incoming wheat flour. This will give a very positive effect for the washing of the starch in the further steps.

Afterwards the different fractions of the three-phase-decanter can be treated separately, as shown in Figure 12.

The concentrate and the sometimes the pentosane fraction too should be sieved to recover very small gluten lumps in order to feed them back to the medium fraction.

In a following process step the medium fraction is transferred to a screening device to separate the gluten from the B-starch milk. The gluten is then treated by a gluten washer to improve the protein content. From the separating device the B-starch milk passes once more a sieving section to recover small gluten particles.

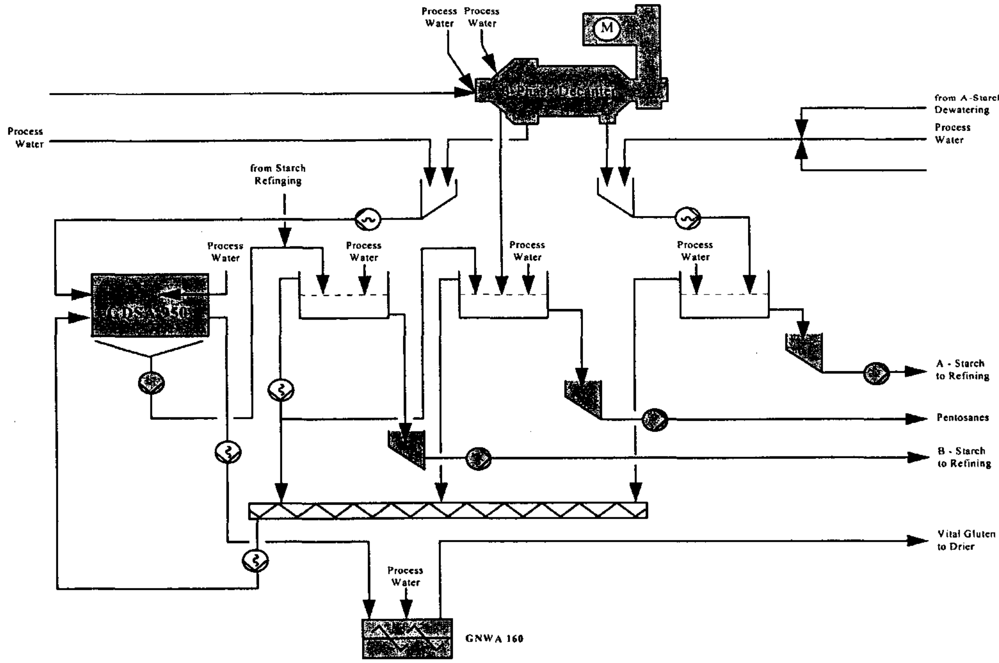

Fig. 12. Possibility to treat the different discharge fractions of a 3-phase-decanter.

Starch washing with three phase separators

The concentrate with the A-starch from the decanter is diluted with fresh water or normally with process water. The starch milk is pumped to centrifugal screens and screened. These screens should have approx. 60 µm mesh to remove fine fibres from the A-starch.

The washing of the starch milk with fresh water can be done with hydrocyclones, separators or a combination of both. To be able to reduce soluble solids in the A-starch milk down to an acceptable value, normally a 12 stage hydrocyclone system is introduced.

A hydrocyclone system has a very high disadvantage for the application of washing of wheat starch. The presence of a high amount of starch granules smaller than 10 µm and the necessity to separate the fine fibres and the pentosanes, are leading to difficulties during performance. For a hydrocyclone unit it is well known, that there can be losses with the overflow, because of its difficulties to separate particles which are smaller than the separation boundary. The application of a three phase separator improves this situation.

A separator type DA 100 is shown in Figure 13. This indicates the principle of a two phase separator.

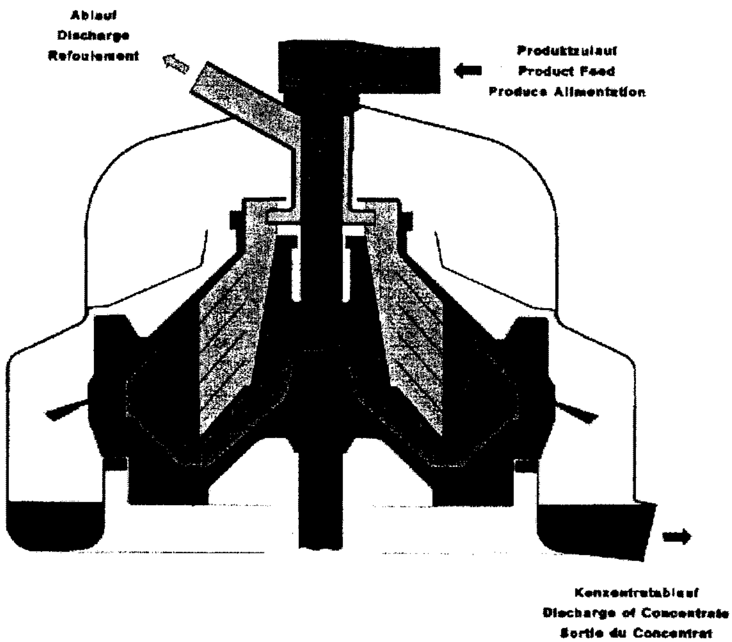

Fig. 13. Cross section of the 2-phase-separator DA 100.

This separator is a vertical centrifuge with a disc stack as clarification area, nozzles for discharging the concentrate and the discharge of the overflow with an installed centripetal pump. The acceleration of the bowl is up to 5000 rpm and the g-force up to 9000. The starch milk enters the separator and by means of centrifugal acceleration distributed at the outer area of the disk stack. The starch granules are separated from the liquid phase and will be concentrated in the outer area of the bowl, where they will be discharged passing the fitted nozzles.

In the disk stack the separation of small suspended solids and small starch granules will take place. If this machine is only used as thickener with up to 12 to 14 degree Baumé in the concentrate, the suspended solids will be concentrated and are leaving the machine through the nozzle phase.

If this separator is used as concentrator with up to 20 ° Bé in the underflow, the small suspended solids will leave the machine with the overflow and will enter the disc stack. In this case the load with suspended solid of the disc stack is very high.

This problem can overcome with the three phase separator SDA 90 (Fig. 14), the newest invention of Westfalia Separator AG for the starch industry.

This machine is equipped with a washing device on the bottom and a special separation disc on top of the disk stack.

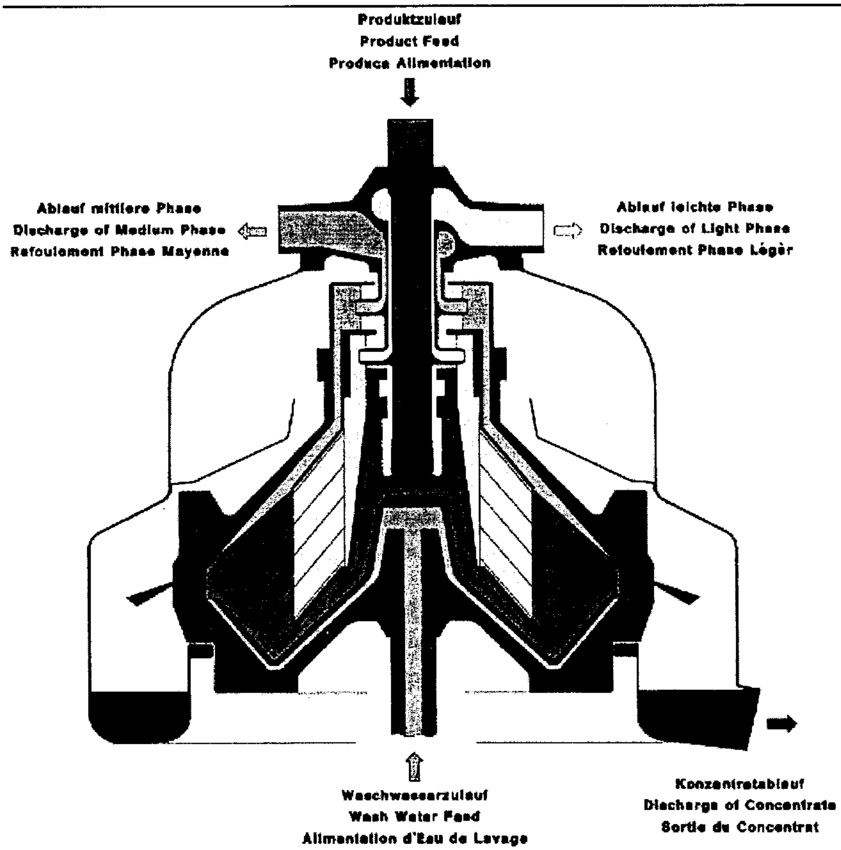

Fig. 14. 3-phase-separator type SDA 90 with washwater device.

The starch milk that enters the machine, is distributed in a channel in the outer area of the disc stack. All the suspended solids are separated from the liquid phase and concentrated in the bowl in front of the nozzle. The A-starch leaves the nozzles together with a smaller part of B-Starch. In comparison to the two phase separator, the concentrate will have a reduced amount of B-starch. The other amount of the B-starch, hemicellulose and pentosanes will enter the channel above the separation disc stack and be discharged over the second installed centripetal pump into the medium phase of the separator. Under these circumstances the liquid phase entering the disc stack has a reduced amount of soluble solids. That means that the load of the disc stack with suspended solid is less and the efficiency is much higher.

With the washing device it is possible to displace the soluble solids directly with fresh water. In Figure 15 is shown the relation between the density of the concentrate, the pressure of the washing water and the amount of washwater.

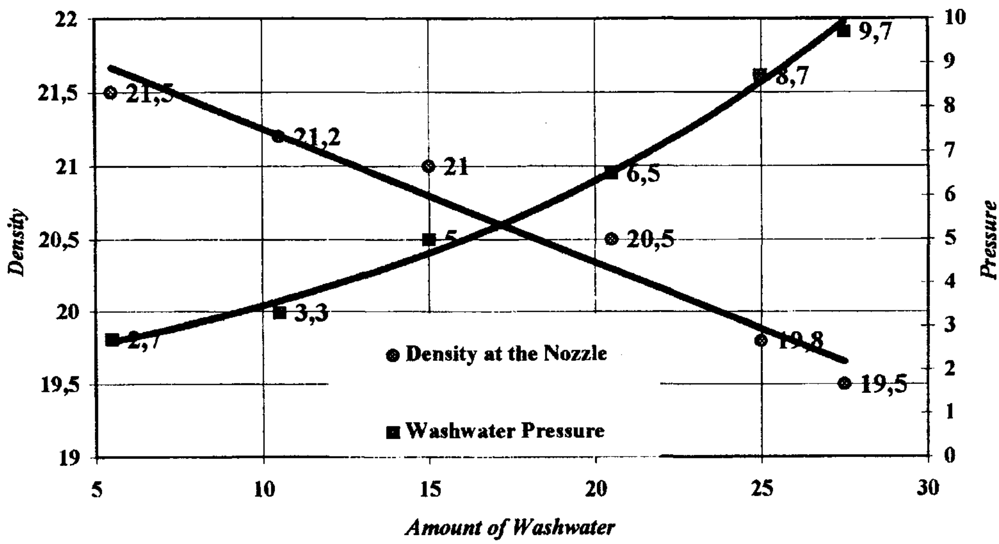

Fig. 15. Density and pressure in relation to the amount of washwater.

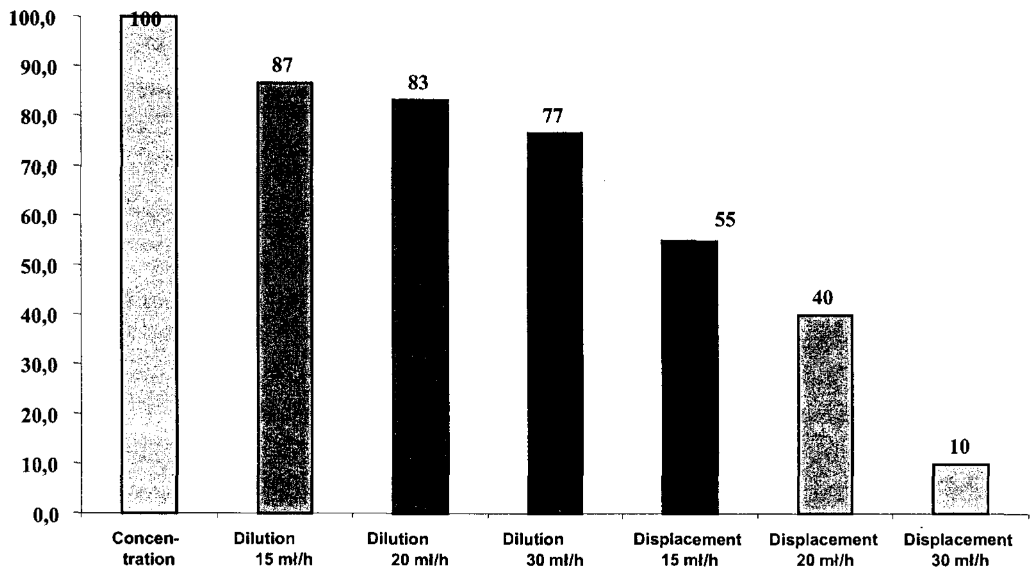

Fig. 16. Reduction of soluble protein content with different washing procedures.

A comparison of the reduction of soluble proteins in relation to the amount of washwater is shown in Figure 16. It can be seen that the dilution of a starch milk to reduce the concentration of soluble proteins is more efficient with the washing device of the three phase separator. Here the soluble solids are directly displaced. These solids are put together with the liquid in the overflow and medium phase. With an amount of 30 m^3/h fresh water, it is possible to reduce the content of solubles down to 10%. If the suspension will be only diluted, the reduction can be only 77%.

In Figure 17 is shown an overall view of the different phases of a three phase nozzle separator. It can be seen that the non starch solids are mainly distributed in the medium phase. The overflow of the machine is relatively free of suspended solids and can be used as process water.

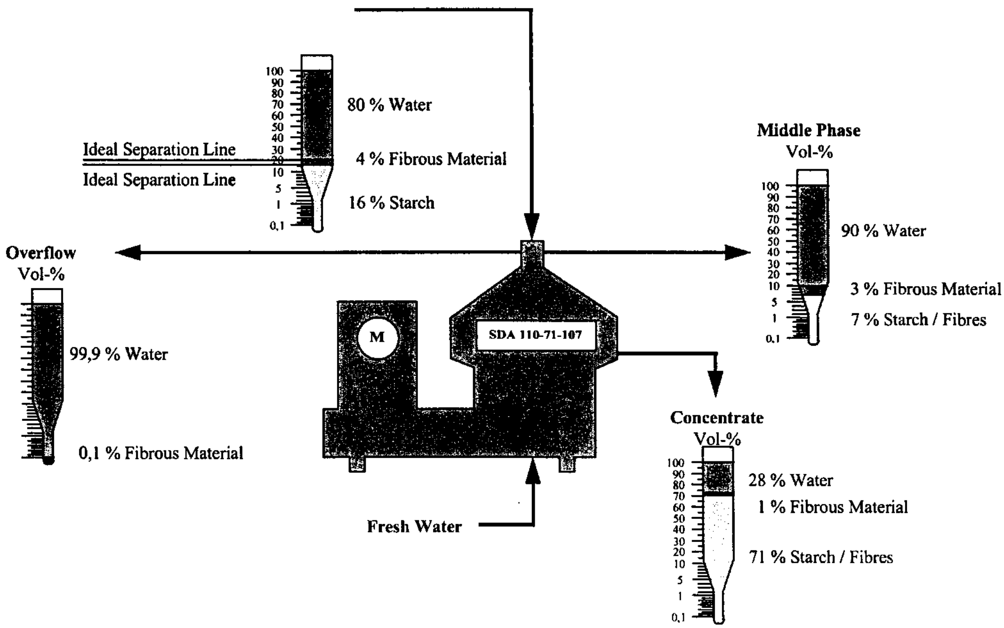

Fig. 17. Spin test of the different phases of a 3-phase nozzle separator.

A starch washing line can be composed out of two three phase separators for the A-starch washing and one three phase separator for the starch recovery. This separator recovers starch milk from the nozzle phase of the three phase decanter and out of the nozzle phase of the first starch washing separator (Fig. 18).

The introduction of an extra three phase separator for the starch recovery has the advantage that the medium phase will discharge the main part of the hemicellulose and pentosanes. These components are coming from the nozzle phase of the decanter and the first washing separator. There can be found as well some small size granule starches. They can be recovered by separators and/or decanters to produce a special fraction of small granule starches.

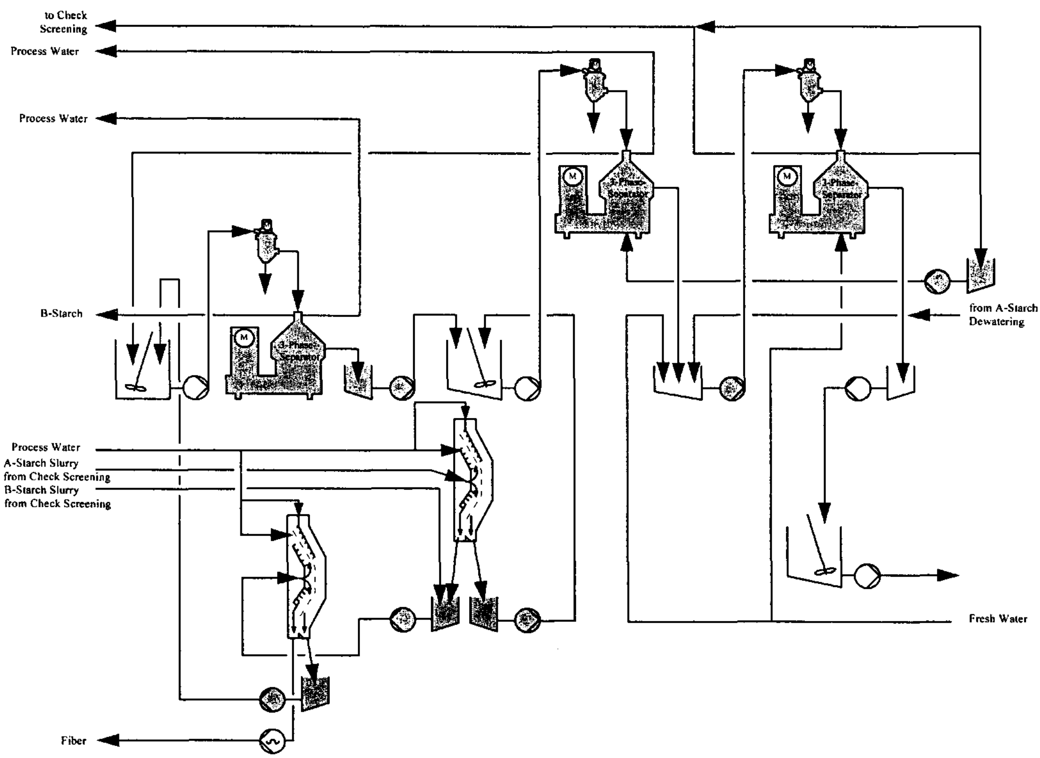

Fig. 18. Example for a possibility to wash starch with a combination of three 3-phase-separators.

Instead of using a second three phase separator in the washing line, a hydrocyclone system can be used. The disadvantage of the hydrocyclone unit is the lower g-force and more losses of small size granule starches in the overflow. This results in high amount of recycling starch in the process (Fig. 19).

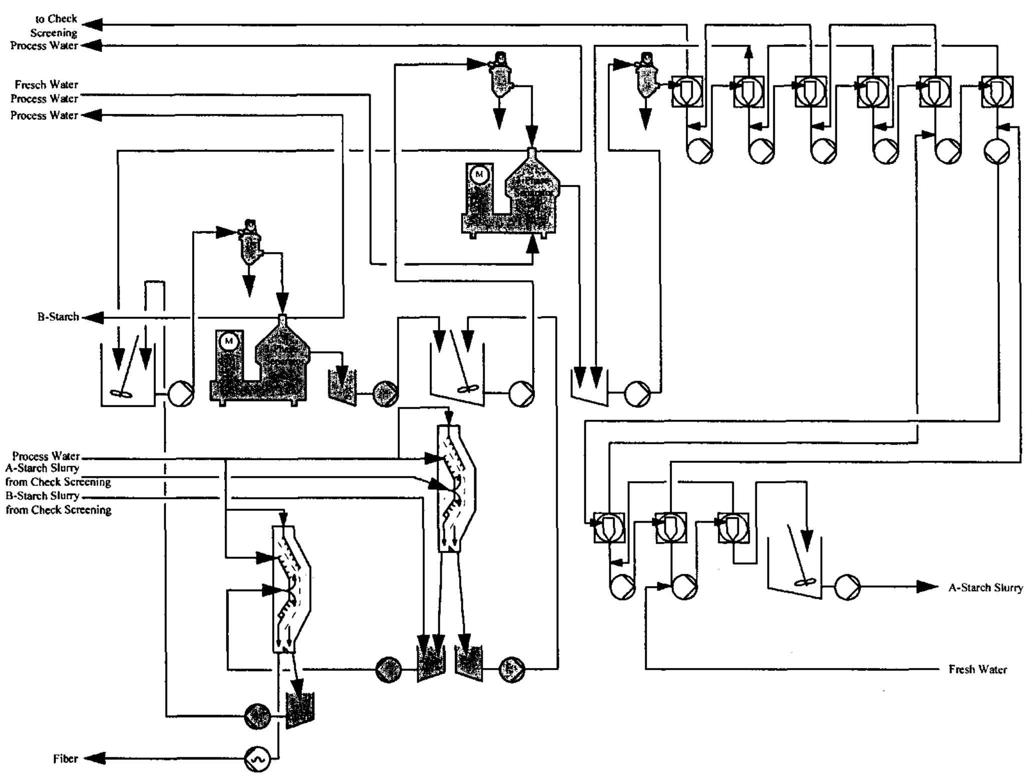

Fig. 19. Washing of starch with two 3-phase-separators and a hydrocyclone unit.

Concept for small granule starch recovery; 3 separate lines

Westfalia Separator AG has developed a modern concept for recovering small granule starch (Fig. 20). The starch washing; concentration and recovery is separated into 3 different lines; the A-plus starch line, the A-minus starch line and the C-starch line. Beginning from the 3-phase decanter, the A-starch coming out of the solid phase of the 3-phase decanter is passing a fibre screen and than is fed to a 3-phase separator. The separator is splitting the feed into an A-plus starch fraction, an A-minus starch fraction and as well as a process-water phase.

The A-plus starch afterwards is washed countercurrently by a multistage hydrocyclone unit. The A-minus starch including fine fibres is fed to the second washing line and enters first a further 3-phase separator. The starch milk from gluten washing is added too. The nozzle discharge of the separator contains the A-minus starch and is washed and concentrated by starch washing separator or decanter.

The medium phase of the 3-phase separator containing very small granule starch and other separable material like fine fibres are directed to the C-starch washing line.

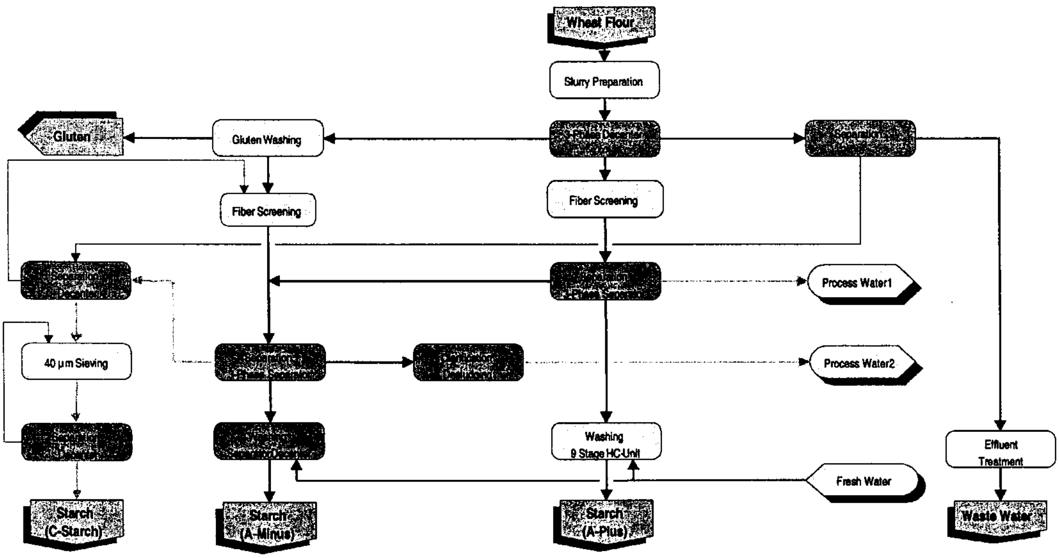

Fig. 20. Concept for small granule starch recovery; 3 separate lines.

A separated small granule starch fraction, collected from the pentosane phase of the 3-phase decanter is also fed to the C-starch washing line. This C-starch fraction is separately washed screened and concentrated by separators/decanters and screens.

This system enables certain advantages e.g.:
1st high yield of starch,
2nd less recycling of small granule starch and other separable particles into the system,
3rd less freshwater consumption.

Situation of the by-products

The pentosane fraction of the three phase decanter can be handled as a liquid by-product for animal feed. Another possibility is to treat it with enzymes, decanting the heavy particles away and concentrate it in an evaporator together with the waste water. Consequently the concentrate of the evaporator can be dried together with fibres or any other dry by-products.

Waste water

The waste water of the plant can be treated in different ways. For example evaporation, the anaerobic or aerobic treatment in a waste water treatment plant.

Yields of the components out of wheat

The yields of the components are of a very big interest for every starch producer. This depends on the recoverable starch, the distribution of the size of starch granules and the content of gluten protein in the flour. The recoverable A-starch can be extracted to an amount up to 85% and it is possible to recover an extra amount of small granule starches up to 12%.

The potential of recoverable gluten protein of the flour can be extracted up to 85 % into the gluten as final product.

Conclusion

This lecture shows that the usage of three phase separators and decanters gives a lot of advantages to improve the wheat starch and gluten processing. It is possible to adjust the process to different raw materials and to optimise the yield of products and by-products, as well as reducing the quantity of effluent per ton of flour.

NOWOCZESNE METODY ROZDZIAŁU SKŁADNIKÓW PSZENICY

Streszczenie

Wyodrębnianie skrobi i glutenu z pszenicy wymaga specyficznych metod. W przyszłości wykonywano to w zasadzie ręcznie. W referacie opisano dwie główne metody (Martin'a i hydrocyklonową) oraz ich zalety i wady.

Nowoczesne metody rozdzielania składników pszenicy obejmują zastosowanie trójfazowego oddzielacza i dekantera lub też połączenia tradycyjnych i nowych metod. Użycie trójfazowego oddzielacza oraz dekantera korzystnie wpływa na proces otrzymywania skrobi i glutenu z pszenicy. Umożliwia też dostosowanie procesu do różnych surowców i optymalizację wydajności produktów i produktów ubocznych oraz zmniejszenie ilości wycieku w przeliczeniu na tonę maki.