PROJECT REPORT No. 248

STUDIES ON THE SEPARATION BY WET AND DRY MILLING OF WHEAT STARCH AND ITS USE IN PAPERMAKING, COMPOSTS AND FERTILISERS

APRIL 2001

Price £3.50

STUDIES ON THE SEPARATION BY WET AND DRY MILLING OF WHEAT STARCH AND ITS USE IN PAPERMAKING, COMPOSTS AND FERTILISERS

by

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This is the final report of a three-year project which started in October 1997. The work was funded under the EU "EUREKA!" programme and the "Wheat for Industrial Needs" project (project no. 169311). Funding for the work at CCFRA was provided equally by MAFF (£250,000 - project no. CEO163) and HGCA (£250,000 - project no. 1997). A copy of the full EUREKA! report can be obtained by contacting Dr. Cauvain at CCFRA.

Abstract

This EUREKA! project involved 10 academic and industrial partners in four European countries. The general aim was to improve the scope of application of wheat and wheat-derived products (starch, gluten and bran) by improving the economy of wheat with respect to other crops. To achieve this objective the integrated production chain was studied to allow better definition of raw material and intermediate product characteristics with respect to end-use requirements.

The project was designed around three inter-linked themes with sub-tasks in each theme:

- Theme I covered endosperm development, structure and fracture mechanics and both encompassed dry and wet processing technologies.
- Theme II evaluated grain processing technologies and investigated use and upgrading of milling co-products.
- Theme III investigated links between flour processing and product quality and the evaluation of the suitability of starch from new processing technologies in key applications.

Factors involved in the formation of A-type and B-type starch granules and their relative quantities were identified. Understanding such mechanisms can provide varieties with improved fractionation characteristics and lead to improved end-use performance.

A range of 500 wheat lines and varieties were assembled and grown in nursery conditions over 3 years. Environmental effects were important in determining endosperm texture and the ratio of A:B starch granules. This study showed that these characteristics are under both genetic and environmental control.

The mechanical properties of wheat endosperm and the effects of moisture content were measured, as well as fracture energies during crack propagation. Such studies, along with data on grain shape, provide information which can be used to improve the separation of endosperm and bran during milling.

A range of pre-treatments of wheat before milling was evaluated. Since the end-products are not required for human consumption, it was possible to include both physical and chemical pre-treatments. The role of wheat moisture, de-branning, the uptake of salts and the effects of enzyme additions were evaluated.

Comparisons between different milling techniques were made for their efficiency in the separation of endosperm and bran. The Satake Peritec pearler, a Jackering system and pin milling were investigated. Separation of starch and gluten was studied using pilot-scale experiments using combinations of variations in temperature, dry matter content and high and low energy inputs.

Two specific non-food end-uses were investigated. Flour and starch were evaluated in papermaking where very low-protein flours exhibited some potential. Branny materials were used successfully in the manufacture of composts and fertilisers.

The economics of the conversion of wheat to industrial products are complex and depend on a number of factors including market prices and total product values (i.e. the sum of starch + protein + bran). This project did not identify a significant cost advantage for wheat compared with other starch-rich crops.

Summary

Introduction and Objectives

The success of EU wheats as a renewable agro-industrial product depends to a large extent on its suitability for end-use and general profitability. For breadmaking, EU wheats have to compete with Canadian and US wheats on price/performance ratio. In other areas wheat competes with other crops, e.g. as a source for the production of starch. The general aim of the project was to improve the scope of application of wheat and wheat-derived products (starch, gluten) by improving the economy of wheat. Economy is defined as the net value of wheat products like flour, bran, starch, and gluten minus the costs of wheat and its integral processing costs. To achieve this, the project combined innovative scientific approaches with the concept of the integrated production chain allowing a better definition and control of quality parameters.

The main problems for wheat starch are related to protein and lipid contamination, viscosity characteristics and the economy of use. In fact, the price of wheat starch is considered by the wheat starch industry as the primary factor restricting its non-food use and a further expansion of the EU wheat starch industry. The co-product gluten also has limitations to its use, caused by discolouration, starch contamination and product variability.

The utilisation of wheat and wheat products in non-food applications is limited. In some cases the use of constituents is identified but the wheat product is economically uncompetitive. In other cases, cheap co-products of wheat processing are available but insufficient research has been done to develop a conversion process enabling their utilisation. The strategy adopted includes the development of an improved understanding of the variation in mechanical properties of raw materials in relation to processing, and hence enables improvements to be made in established conventional wheat processing for food uses. At the same time, an improved physiological understanding of wheat development and of wheat starch biochemistry opens up new ways to dramatically increase the yield and purity of wheat's prime industrial product, wheat starch.

Grain fractions, as starting materials for industrial uses must be obtained at minimal processing costs. Starch and gluten production by current methods is heavily dependent upon water usage and subsequent disposal. The economics of the process are heavily influenced by the need to ensure environmentally responsible disposal. The application of wet technologies, necessary for the production of concentrated fractions, is unavoidable when aiming at higher

added value products. Optimisation and adaptation of both dry and wet fractionation technologies by improving raw materials and a better definition of production requirements, will open new and promising perspectives for the wheat processing industry of the future.

In order to achieve this perspective, the project was designed around three themes: -

- Endosperm development, structure and fracture mechanics
- Grain processing and upgrading of co-products
- Flour processing and product quality

- ***Theme I***

  Endosperm development, structure and fracture mechanics aim at a better understanding of the relationship between structural and mechanical aspects of wheat endosperm fractionation. Modelling the mechanical properties of endosperm allows the development of improved dry fractionation technologies (leading to improved separation, performance and better-defined fractions).

  Wet separation of wheat flour results in two main products: A starch and gluten. The yield of A starch is determined by both the endosperm content of the grain and the relative amount of large so-called A starch granules. Understanding the physiological basis of starch granule formation will open new ways to produce high yielding wheat varieties. The purity of wheat starch is an important quality criterion. Background research into the identity of specific starch granule bound proteins and their mechanism of interaction will lead to new strategies to further purify starch at lower processing costs.

- ***Theme II***

  Grain processing and upgrading of co-products, aims at a) integrating knowledge of Theme I in the development of new breeding and growing concepts for raw material improvement, b) the improvement of dry separation by adaptation of current pre-treatments based on fundamental information from Theme I, and c) improving the added value of co-products from dry and wet separation processes.

- ***Theme III***

  Flour processing and product quality, integrates knowledge of Themes I and II in the development of adapted processing concepts. At the same time Theme III aims at the evaluation of the suitability of starch and gluten from these new processes in key areas of application.

In achieving the stated objectives a series of tasks was addressed. These tasks formed a chain of requirements. It starts with the definition of both food and non-food related economic and quality restrictions and must lead to optimisation of the starting material and perfecting the separation processes. This will result in the production of a series of gluten and starch evaluated for non-food applications. The clear purpose of this 'production chain' is improve the economic utilisation of wheat starch to such an extent that it will be able to replace other starch sources on the European market and generate additional flexibility for wheat as an industrial crop in the EU.

Potential benefits to Levy Payers

This project was aimed at the concurrent development of dry and wet wheat processing technology specifically designed for the food or non-food application of wheat constituents.

Wheat starch needs to be cheap and of constant high quality, that is devoid of proteins and lipids. These contaminants cause problems in derivatization in terms of product homogeneity, appearance (colour) and conversion (viscosity, filtration). As a potential source of starch, wheat has several advantages over maize and potato. The growing of wheat requires far less agro-chemicals such as pesticides. Wheat is relatively easily stored and is available throughout the year. However, wheat endosperm contains two types of starch granules. In addition to large A-type starch granules wheat seeds contain a large amount (15-30%) of smaller B-type starch granules. Moreover, isolated wheat starch contains a variety of associated proteins and lipids. These factors negatively influence the yield and quality of wheat starch. In addition, these factors together with the storage proteins (gluten) determine the hardness of the endosperm in an unknown manner. The harder the endosperm, the greater the loss in terms of damaged starch as a consequence of the milling process. In terms of raw material used these issues are key to the improved utilisation of wheat.

The research described provides important underpinning knowledge on the development of endosperm texture. The molecular biological study has highlighted one of the important processes involved in endosperm development in the growing plant. It has also contributed to the fundamental understanding of plant growth regulatory factors. The biochemical studies have established the basis for practical means to modify the unwanted interactions in the endosperm. The combination of botanical, analytical and mechanical approaches has helped to identify the forces which determine the mechanical fracture of endosperm. This knowledge will open up new and more effective means of separating starch and gluten and improve their suitability for end-use. The tools developed and knowledge obtained will improve our understanding of the processing of other plant seeds (maize, barley).

The technical benefits from the project include improved knowledge of grain fractionation and methods of separating the starch and protein components. Pre-treatment of the grain may add to production costs but improved raw material quality may be offset by lower end-use costs.

A new use for bran to a major by-product from flour milling processes has been identified and evaluated on a semi-industrial scale. Composted bran materials have a number of potential uses in horticulture.

The economics of the conversion of wheat to industrial products are complex and depend on a number of factors including market prices and the total product (e.g. starch-protein-bran) values involved. The results of this project have not yet identified significant cost advantage for wheat compared with other starch-rich crops. At present the economics advantage appears to be neutral.

Endosperm Development

Institutes involved:

Centre for Phytotechnology UL/TNO, TNO Department of Applied Plant Sciences, CCFRA

Several approaches were undertaken to identify factors involved in the formation of A-type and B-type starch granules. The formation of B-type starch granules in wheat endosperm was studied using TEM and CSLM techniques. B-type granules were formed in protrusions emanating from A-type granule containing amyloplasts. These protrusions form connections between amyloplasts.

To identify a possible primer for starch biosynthesis, self-glucosylating proteins were studied. It was found that two different classes of proteins could be identified: RGP1 and RGP2. Several characteristics of these proteins were determined as well as the effects of over expression and antisense inhibition. The proteins are not likely to be starch primers, but do play a role in sugar metabolism. Starch granules from transgenic plants that have altered RGP1 and/or RGP2 expression had altered properties as well.

Studies on the effects of low light and high temperature on grain and starch granule development, showed that the amount of B-type granules was not correlated with the degree of endoreduplication. This suggests that endoreduplication does not cause the process of protrusion formation.

The previously identified protein unique to the *Triticeae* tribe of cereals (wheat, rye, barley) was analysed. This protein could only be identified in starches having a bimodal size population of granules, and a unique oblate ellipsoid form for the larger A-type granules. Attempts to purify this protein did not yield a sample suitable for sequencing.

Grain And Tissue Mechanics And Dynamics Of Treatments

Institutes involved:

CCFRA, INRA, LMGC-CNRS, University of Reading

During production of starch from wheat, a dry fractionation is performed to separate endosperm from bran and germ, and to grind the endosperm to flour prior to wet separation. It is desirable to maximise the amount of flour produced from a given mass of wheat for economic reasons, and to minimise the inclusion of bran and embryo in the flour for reasons of product quality. Simultaneous optimisation of these two constraints is a critical factor in optimising the performance of the dry fractionation process.

Flour particles typically vary in the relative amounts of protein and starch that they contain. By air classification or other means, it is possible to separate starch- and protein-rich fractions from flour, the former being a better starting material for starch production. Practical studies of the efficiency of separation achieved by air jet milling and air classification have been conducted in another task of this project. To optimise the efficiency of such a process and the degree of purification achievable, it is desirable to be able to enhance physical dissociation of starch and protein as discrete particles during dry milling. This may be achieved by modifying the texture by pre-processing of wheat prior to dry fractionation.

It is thought that the mode of initial fracture in wheat may be relevant to the efficiency of separation of endosperm from bran, and this was studied by Finite Element Modelling (FEA), using data on the bulk mechanical properties of endosperm measured at Reading University and at LMGC, and using data on grain shape measured at CCFRA.

The mechanical properties of bulk endosperm were measured by the University of Reading and by LMGC. Reading studied the anisotropy of these properties and the effects of moisture content on them, as well as the fracture energies during crack propagation.

LMGC studied the distinction between the properties of ‘hardness’ and ‘virtuousness’, used by millers to describe endosperm texture, and used model granular materials to understand the roles of the elastic modulus of the component particles and the adhesion between them in determining fracture properties. 2-D and 3-D models were constructed. Measurements of grain shape for use in the models were made at CCFRA. Grains were embedded in epoxy resin and mounted on a metal stub. Sections were cut using a microtome. The stub was then placed in a fluorescence microscope, using a machined flat to locate it accurately in position. An image of the cut grain surface was taken using a video camera and stored digitally. Further sections were then cut until images had been obtained for the entire length of the grain. By using fluorescence imaging, it was possible to image the aleurone layer and to determine the shape of the endosperm cavity as well as the external shape of the grain.

CCFRA studied several practical pre-treatment regimes and identified one that may assist in reducing endosperm hardness. INRA made practical studies of wheat fractionation on a small scale instrumented mill, and related the applied torque and milling energy to practical measures of the milling quality of wheats from various European sources.

The mechanical properties of wheat endosperm were characterised using a new method for preparing test specimens of a specified geometry. A distinction between virtuousness and hardness was made, based on rupture energy and elastic modulus respectively. This is of benefit in classifying wheat samples so that their suitability for industrial processing can be identified. Using model materials and numerical models, a better understanding has been gained of the effect of adhesion between components at the microstructural level on these properties. The dependence of endosperm properties on moisture content was also determined, with relevance to optimisation of conditioning regimes. Practical conditioning regimes for non-food applications were tested. Conditioning with polyphosphates offered a promising approach for softening wheat endosperm. A small-scale micromill was developed capable of measuring torques and grinding energies for small samples of wheat. A milling index was developed, incorporating the milling energy and information on particle size reduction and sample purity. This related well to the ranking of milling performance of wheat samples in larger scale milling systems.

Technological Aspects of Physical and Mechanical Treatments

Institutes involved:

CCFRA and INRA

The ultimate objective of this task was to improve production of starch-rich and protein-rich fractions from bread wheat by dry milling techniques, thus perhaps avoiding the necessity for wet separation of gluten and starch. It was considered that methods to increase the softness of the endosperm would contribute to this objective, not only in dry milling by giving cleaner fracture at the starch granule surface, but also in wet procedures by reducing losses of starch as swollen damaged granules. Ideally, such treatments would not harm the baking functionality of the protein fraction. The reagents selected for laboratory-scale trials were polyanionic salts, particularly sodium polyphosphates of higher molecular weight, because there was evidence from studies of the fracture of dried pasta that such salts can weaken the interaction between starch granules and the protein matrix. Such salts, cheaply available and non-toxic, and unlikely *a priori* to affect gluten quality, were complementary to the more aggressive chemical treatments being used at INRA-Montpellier for research purposes within this sub-task.

Initial experiments were done with standard wheats that had been de-branned by scouring, to ease the uptake of salts into the endosperm during conditioning. Softening of the endosperm, relative to conditioning with water alone, was judged by the Particle Size Index of white flours produced on a Brabender Quadrumat Junior rollermill. The salts gave significant softening. Similar experiments with grains with intact bran gave a lesser softening effect, presumably because penetration of the salts was hindered by the water-resistant test layers, so grains were subjected to light scouring in an attempt to improve uptake. Penetration of the salts, assessed by scanning electron microscopy (SEM) X-ray microanalysis for phosphorus in cross-sections of treated grain was substantial, but not complete, in the de-branned grain.

Raw Materials

Institutes involved:

ULICE

The traditional utilisation of wheat for human food mainly as bread and biscuit has been largely taken as major objective by wheat breeders. This has led to the improvement of the raw material for agronomic characteristics: yield, disease and lodging resistance as well as protein content and protein quality for bread and biscuit quality. Efficiency of classical breeding procedure for these traits has been known for many countries in Europe where yield and baking quality have progressed tremendously. This trend has certainly reduced genetic variability for other characteristics among major wheat varieties grown in Europe. In order to improve the scope of industrial application of wheat, new attributes should be addressed that will reduce process cost or enhance commercial product value. These new characteristics could be identified and developed from a genetic variability survey.

The programme developed in 3 steps:

- general germplasm screening,
- examination of elite lines,
- production of samples.

A range of 500 lines and varieties issued from French, European and international sources were collected and grown in a nursery over 3 years.

Elite lines for soft texture of endosperm and ratio of A/b granules were re-examined after seed increase. Only one line had a high A/b ratio and one line a high degree of endosperm softness. A trial network was designed to test both lines under different agronomic environments. Environment effects were quite important for both traits, showing that the characteristics being studied were under genetic and environment control. Further analysis would be necessary to confirm the behaviour of these lines.

Grain samples of line A-type were experimentally mill and micronized. Flours were assessed under air classification with a pilot system. Efficient separation between proteins (fine particles) and starch fraction (larger particles) was shown to be better than with other control varieties.

At the first stage, two lines of differing endosperm hardness, soft and mid-hard, NSA 2 and ULI3 were multiplied for milling experiment. A second range of lines representing a range of the general genetic variability were further increased and milled for starch extraction analysis. Finally, the high A ratio line was multiplied for starch granule analysis, and small samples of hyper soft were sent for dry fractionation and paper making evaluation.

Evaluation of a large genetic variability for new characteristics did prove to be fruitful as lines were identified that could lead to improvements in process efficiency for milling, dry fractionation and maybe papermaking.

Structural Basis of Grain Fractionation and Pre-Treatments

Institutes involved:

INRA, University of Reims,TNO Food Research, Meneba Meel BV

Improved control of grain texture and of fragmentation or fractionation processes rely upon a better understanding of various grain interfaces: between starch granule and protein matrix, between endosperm cells, between starchy endosperm, aleurone layer and pericarp. An identification of the bonds or interactions at the various grain interfaces was attempted to devise chemical or physical pre-treatments enabling the achievement of histological or molecular separation through dry or semi-wet procedures. Special emphasis was put on: (i) identification of protein and arabinoxylan components that are present at the surface of the various grain interfaces using micro spectroscopic techniques and (ii) identification of biochemical changes resulting from chemical and mechanical pre-treatments. The chemical and structural characterisation of interfacial components by Raman microspectroscopy suggested that kernel hardness might either result from an increased α-helix conformation of the storage proteins, or from an increase of the ratio of ferulic content to arabinoxylans in cell walls. Among the various chemical pre-treatments of grains using solvents designed to destructurate the various bonds or interactions of the wheat grain (ethanol, sulphuric acid, sodium hydroxide, basic or acid sulphite) the basic sulphite had marked effects on the fractionation behaviour and the chemical composition. The association between chemical pre-treatments and new dry processes (ultra-fine grinding of flours) produced low-protein (≈ 2 %) starches. However, any conclusion in terms of specific starch-protein (or starch-lipid-protein) bonds or interactions that would make the basis of endosperm hardness or texture were difficult to draw.

The essence of tempering is to increase the toughness of the bran and to reduce the hardness of the kernel. The best result will be obtained if the process is performed uniformly so little variation between kernels occurs.

The effect of a xylanase was tested on a small-scale system that performs measurements on single kernels, the Single Kernel Characterisation System (SKCS).
Enzymes added to the tempering water could, after penetration into the bran layers, help to separate bran from the endosperm. This may lead to a higher flour yield and perhaps also to a reduction in starch damage.

Exploratory tests with the SKCS showed that the peak force measured during crushing mainly resulted from the dry matter of the kernel. Increased moisture content did not alter the required force for crushing. Perhaps the higher endosperm softening at a higher moisture content was compensated for by a higher toughness level of the bran. The effect of xylanase addition was detectable by measuring the peak force/weight. Shortly after conditioning (5 to 8 hours), xylanase addition resulted in an increased peak force/weight. After 24 hours conditioning, the xylanase effect was reversed. As a result the wheat was softer at 24 hours conditioning due to the xylanase. The same effect would be achieved however using higher moisture contents before milling.

Meneba developed an alternative short milling procedure incorporating a pin mill to remove the flour from the bran. In this system a higher moisture content can be applied, which reduces the starch damage level. A reduction of more than 3% was obtained. The particle size distribution of the material was however distinct from conventional starch flour. It was expected that this would cause problems in the separation process. This hypothesis could not be tested on pilot scale.

Other potential improvements were investigated using new milling equipment. In general this equipment reduces the number of milling steps in a mill and it is expected that this will lead to a reduction in starch damage.

Flour samples were obtained from a mill system incorporating the Satake Peritec pearler. In this system the wheat was pearled and subsequently milled in a short system. A comparison was made with a standard milling system. Flour yields, ash contents and starch damage were not significantly different, so the samples were not investigated further.

Using a Jäckering system in the pilot mill proved to be quite successful. This system reduces a mill stream in particle size by impact. The overall result is a reduction in starch damage. Compared to standard starch flour production with 11-12 % starch damage, the Jäckering flour only had 6.3 to 8.8% damaged starch at comparable or higher extraction rates.

The final approach for a reduction in damage starch was the use of soft wheat to replace hard wheat. Milling soft wheat usually results in lower flour yields compared to hard wheats. In the trial carried out, the flour yield was reduced by 2.2% at comparable ash contents. The starch damage in the soft wheat flour was 2.8% lower than in the hard wheat. This approach does not require any investment in equipment and is therefore most promising for the milling industry.

Adding Value to Co-Products

Institutes involved:

Levington Agriculture and CCFRA

This aspect of the project followed on from pilot studies in 1996 and 1997 funded by the HGCA (Project Reports 144 and 157) in which small scale composting was carried out on bran and various carbon-rich wastes, and the resulting products successfully tested as growing media for tomatoes and as a turf top dressing.

The value of wheatfeed fell by 50% from 1996 to 1997, affecting the milling industry economically. This aspect of the project was to investigate whether alternative uses for wheatfeed were available in the horticultural sector, where product values are generally higher than in agriculture, compared with as cattlefeed. As the organic growing industry was also increasing, and the requirement would be for composting to be carried out on any materials brought on to an organic farm, different methods of composting were also investigated. The composting process releases some of the nutrients from their organic form, making them more readily available to plants.

Composting was carried out on small (100 litre) and large (30 cubic metre) in-vessel systems with controlled airflow and temperatures. Wheatfeed pellets were used, as supplied by mills, and water added to bring the moisture up to 50-60% that is ideal for the composting process. It was found that the wash water used from the starch industry contained chloride in amounts excessive for plants and so could not be used further.

The wetted wheatfeed could not be composted without the addition of a bulking agent as it starts to ferment in the absence of oxygen. Additives tested were shredded bank notes, friction bran, carbon perlite, and an inert plastic aerating agent. All mixtures performed well with the carbon perlite compost showing potential as a fertilizer carrier. Wheatfeed with water and the inert bulking agent was considered to be the recipe with the most potential for commercial application to produce a component for growing media or an organic-based fertilizer.

Wheatfeed contains the following nutrients before composting: total nitrogen 2.6%, total phosphate 2.1% and total potash 1.4%. The carbon to nitrogen ratio is 15 indicating that nitrogen will be released during the composting process. This makes wheatfeed a useful activator for the composting of high carbon wastes. On its own, composted wheatfeed became a fertilizer strength product with the added benefits of retaining water and being able to replace some of the volume in a growing medium mix. The degree of composting was found to affect the fertilizing properties of the material. Composting for a short period, during which temperatures were raised to kill any plant pathogens, released some of the nitrogen whilst retaining some slow release effects. Mixed with peat, coir or woodfibre materials the composted wheatfeed provided all of the nutrients required growing a range of plant species. The rate of addition was successfully tested in growing trials, and storage tests were conducted to study the changes that took place.

The composted wheatfeed was found to have good effects as a fertilizer for cabbages and wheat, and as a turf fertilizer. Some moss cover reduction was also seen as a result of improved grass vigour.

Starch and Gluten Production

Institutes involved:

TNO Food Research and AVEBE

The aim was to test raw materials from other tasks and optimise wheat starch production in terms of yield and purity by improving separation and purification.

The design of the pilot scale experiments with new equipment involved combinations of variations in temperature, dry matter content and high and low energy input. The experiments showed that weak and strong flour types could be processed in the system. The reproducibility of the system was very low and so no conclusions on yield improvements could be made. Furthermore, poor gluten agglomeration was obtained at temperatures between 20°C to 30°C for both flour types. In the pilot system, the strong flour required a higher energy input than the weak flour for optimal development. It was concluded that a 3-phase decanter system would be able to process flour types of various quality, so no restrictions on raw material type are involved. No conclusions on the yield improvements of the system could be drawn.

From laboratory-scale experiments it was concluded that a reduction of damaged starch will result in an increase in recoverable starch yield. The increase in yield will depend on the actual level of damaged starch in the flour. Besides the effect on starch yield, an effect on processing costs is also expected.

The optimisation of the wheat starch separation was tested using new equipment of Westfalia Separator on pilot-scale, a three-phase decanter separator. The systems was tested for two aspects:

- the improvement of yields
- the performance for various flour types for various processing conditions

Prior to the pilot-tests, small scale tests were carried out to identify critical processing parameters. These small-scale tests would indicate if wheat flours of distinct qualities could be processed and what kind of process adjustments should be performed in case of failures.

Two flour types were tested using the standard AVEBE-Latenstein laboratory separation method (large-scale glutomatic type). In these experiments temperature, flour/water ratio and mixing time were varied. The strong flour type (Kluut) performed well at a low temperature (20°C), a flour-water ratio of 1 to 0.9, and a mixing time of 30-50 seconds. The protein recovery for this flour type was 76%. The weak flour type (Zwaluw) could be processed only if temperature was raised (35°C), more water was added (flour/water ratio 1 to 1.15) and mixing time was reduced (25 seconds). The protein recovery obtained was less than 67%.

To establish a relationship between damaged starch content and the yield of recoverable starch, flour samples from hard and soft wheat varieties were investigated. Including all the data available, it appeared that there was no linear relationship between damaged starch and starch yield. In the range between 6 to 8% damaged starch, an increase of 1% of damaged starch resulted in a more than 1% reduction of starch yield. Above 9% damaged starch, the reduction of starch yield appears to be far less (ca. 0.5%). A reason for this may be the change in viscosity of the system, the viscosity of the system will be increased with higher starch damage. At low damage levels, this increase will not affect the separatability of the granules. At high starch damage levels, it will become more difficult to separate the damaged and non-damaged granules. The recoverable starch fraction will therefore contain more damaged starch. In production this can only be removed by using more water or by increased centrifugation energies. Thus, damaged starch results in lower starch yields, but also in higher processing costs to meet quality specifications.

Evaluation Of The Use Of Produced Starches In Paper

Institute involved:

Centre Technique du Papier

The objective was to evaluate the suitability of flours in paper coatings. Flours were selected by INRA and ULICE and pre-treated through various methods. The various treatments performed on selected flours were :

- Turboseparation.
- Chemical treatment by the addition of Tixosil or not during the papermaking process.
- Mechanical treatment by separation or separation and grinding
- Mechanical treatment by various grinding methods
- Decreasing the residual protein amount in flours

The samples were tested at laboratory scale for the following properties:

- Flour cooking:
- Control of the flour solution properties by visual aspect and retrogradation phenomenon.
- Laboratory size-press treatment.

- Control of the treated board and paper properties in particular optical and strength properties.

Whatever the flour or cooking process, no problem appeared during cooking. No retrogradation phenomenon appeared and there was no residual grain.

The main problem encountered was the very low binding power of the flours, resulting in very low strength improvements in treated papers and boards. The most interesting flour, from the papermaker point of view, were the flours containing a low amount of residual proteins.