The protein extracted from potatoes is a valuable by-product for the starch sector. A study carried out by ARVALIS – Institut du vegetal / ITPT helped identify which factors promote an increase in the proportion of recoverable proteins.

The industrial starch extraction process requires water, which, at the end of the cycle, generates effluent rich in organic nitrogen (see insert 1). This effluent is then spread on fields near the plants.

In order to comply with environmental requirements in terms of nitrogen emissions, and to restrict the spreading zone, part of the proteins is extracted for use as by-product in animal feed, by the chemical industry for fermentation processes or, more recently, as an ingredient for human consumption. Increasing the protein content in tubers, and more particularly the recoverable part, is therefore a major objective of this sector.

With this in mind, a long-term study, carried out by ARVALIS-Institut du vegetal / ITPT, in partnership with various industries involved in this sector and UNPT (see insert 2), shows the relative impact of various production factors on those criteria.
Simplified starch extraction process and glossary

Water is an essential element of the potato starch (flour) extraction process. Water management is therefore crucial, both in terms of quantity used and quality of the water discharged. Effluent from starch plants contains water used to wash tubers and water resulting from protein starch extraction.

One to two thirds of the total nitrogen contained in the tuber are in protein form. Those proteins represent roughly 2% of the fresh weight and over 90% of them are water-soluble.

The extraction of starch potato protein from the fruit water is done in two stages: acidification of the solution to bring the protein back to the isoelectric pH (close to 5), then thermal coagulation at 110-120°C. The coagulated proteins are then recovered through a decantation or centrifugation process, and then dried. The term “coagulable proteins” is therefore applied to soluble proteins present in fruit water recovered as described above.

Those soluble proteins mainly contain patatins (around 38%) and protease inhibitors (around 50%). They account only for part of the proteins found in the fruit water and therefore of the protein contained in the tuber.

The term “total proteins” describes all the proteins contained in the tuber. The total protein content is obtained by multiplying the result of the nitrogen content found in the tuber using the Kjeldahl method, by 6.25. As for the recovery ratio, it is the proportion of total protein that can be coagulated.

The variety: a key element

The analysis of the varietal trials database shows the coagulable protein content (Cp) is usually between 1.0 and 1.5% of the fresh weight for a recovery ratio between 48 and 62%. Individual samples, however, can vary between 0.8% and 1.7% for coagulable proteins and 40 to 70% for the recovery ratio.

The coagulable protein content is linked to both the total protein content and its coagulable proportion.

### Relative impact of production factors on coagulable proteins (Cp) (tab. 1)

<table>
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<tr>
<th>Factors</th>
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</tbody>
</table>

A positive impact is symbolised with « + » and a negative* Difference between Centaure and Kardal average impact with « - ». The following categories were used:
- ± 1.4% variation =
- ± 1.5 to 4.9% variation : + / -
- ± 5 to 14.9% variation : ++ / - -
- ± 15% variation and above : +++ / - - -

The variety: a key element

The analysis of the varietal trials database shows the coagulable protein content (Cp) is usually between 1.0 and 1.5% of the fresh weight for a recovery ratio between 48 and 62%. Individual samples, however, can vary between 0.8% and 1.7% for coagulable proteins and 40 to 70% for the recovery ratio.

The coagulable protein content is linked to both the total protein content and the recovery ratio (with a level of correlation of 65 and 35% respectively). In spite of a degree of interaction with the year and location, the impact of which is never by itself very significant, the variety plays a predominant role, both for the protein content and the recovery ratio (figure 1). The reference variety, Kaptah Vandel, which is always competitive in terms of starch production level/ha, is however not very competitive in terms of coagulable protein content, which is usually around 1%. This figure is partly due to a recovery ratio under 50%.
Two recent varieties, Centaure and Kardal, increasingly popular over the past few years, are performing much better (1.2 to 1.3% for 60 to 62% recovery ratio). Figures obtained for those varieties in the Villers-Saint-Christophe 2003-2004 experiment, fit perfectly with those results and the increase in protein content has been assessed at around 30 to 40% compared with Kaptah Vandel (table 2). Very recently registered varieties, such as Pollux, which has a recovery ratio of between 65 and 70%, let us expect an even bigger increase.

In 2003, which was particularly dry and hot, the irrigation of Centaure was used efficiently and resulted in an increase in tuber yields of around 10 t/ha at maturity with rate X. However, this increase in yield was accompanied by a reduction in starch content (19.6 instead of 21.2%) and coagulable protein content (1.2 instead of 1.4%) with however an increase of around 1500 kg of starch and 50 kg of coagulable proteins per hectare.

### Appropriate nitrogen rate

In 2003 and 2004, the increase in the amount of nitrogen applied resulted in an increase in total and coagulable protein contents. However, it had a minor impact on the recovery ratio (table 1 and figure 2).

The low rainfall and very high temperatures in 2003 meant that the nitrogen input was not properly utilized, the optimum rate calculated for the starch yield/ha being rate X-80. In such circumstances, fertilisation exceeding this optimum rate helped to significantly increase the coagulable protein yield, at least up to the rate (X) indicated by the balanced method.

In 2004, which was much more favourable to crops, the optimum rate for the starch yield/ha turned out to be identical to the rate necessary to maximise the coagulable protein yield (rate X+40). Compared with rate X, we noted an average increase per hectare of 300 kg of starch and 31 kg of coagulable proteins.

In view of such results, nitrogen fertilisation therefore seems to act as a relatively efficient "lever" as far as coagulable protein content and yield are concerned. This is particularly true when the absence of irrigation on 90% of the area makes it difficult to use nitrogen management tools such as Jubil® or N-Tester® for this crop. In average conditions, the optimum rate, for those criteria, is very close to the rate calculated for the starch yield/ha (rate X).
Achieving adequate maturity

The monitoring of total protein content in tubers has shown that its level increases regularly with the lengthening of the plant cycle; it rises on average from 1.5% of fresh weight at the beginning of July to over 2% near maturity.

In 2003, because crops reached maturity extremely early due to the weather, the development of protein and starch as well as tuber yield were extremely limited, if not nonexistent, between the end of August (date 1, which is when starch plants start up) and the harvest of more mature plants in mid-September (date 2) and at the beginning of October (date 3) (figure 3).

Conversely, in 2004, we noted that harvest when crops were not mature enough (date 1) resulted in a drop in average coagulable protein content of 14 and 10% respectively compared with date 2 and 3 harvests. As with starch, the increase in tuber yield at the end of the cycle can lead to a drop in protein concentration when harvest takes place later on in the season. The impact of maturity on the recovery ratio seems low. However, a slight downward trend was noted with maturation (table 1 and figure 3).

The coagulable protein yield increase mainly depends on a tuber yield increase.
Limited losses during storage

In storage, (figure 4), potatoes consume sugar to breathe and lose water by transpiration. This phenomenon mainly results in starch and tuber weight losses proportional to the length of the storage period. The starch content, however, remains relatively stable, as does the total protein content and its coagulable ratio. Protein loss seems less directly linked to the length of the storage period than starch and tuber weight loss. After four months in storage, the average coagulable protein loss is 5.4% compared with 7.8% for starch and 8.2% for the tuber weight.

Long-term study carried out in conjunction with starch industries and producers

The impact of the variety, the type of year and of the location of the crop has been assessed from the database of varietal trials conducted by ROQUETTE S.A. and AVEBE France (source: Chambre Syndicale de la Fécule). The whole database focused on around 20 different varieties over seven years and in six locations:

- AVEBE France: 15 to 20 varieties x 7 years (1995-2001) x 1 location,
- ROQUETTE S.A.: 10 varieties x 3 years (1999-2001) x 5 locations,

In addition, the Institute carried out a multifactorial experiment in 2003 and 2004 at its Villers-Saint-Christophe (northern France) facilities:

- 3 varieties: Kaptah Vandel, Centaure, Kardal,
- no irrigation; Impact of irrigation on Centaure studied in 2003,
- 4 nitrogen application rates: 0, X calculated using the balanced method (based on the nitrogen content of the soil at planting), X-80, X+40 (X = 195 kg/ha in 2003 and 150 kg/ha in 2004),
- 3 harvest dates: 20th August (date 1), 10th September (date 2), 1st October (date 3),
- for the last harvest and rate X: changes during 4 months in storage (St1 to St4) at 3°C and 7°C.