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Expert system for stored malting barley quality maintenance

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QualiGrain

<http://www.bordeaux.inra.fr/qualigrain>

**Expert system for stored malting barley quality
maintenance**

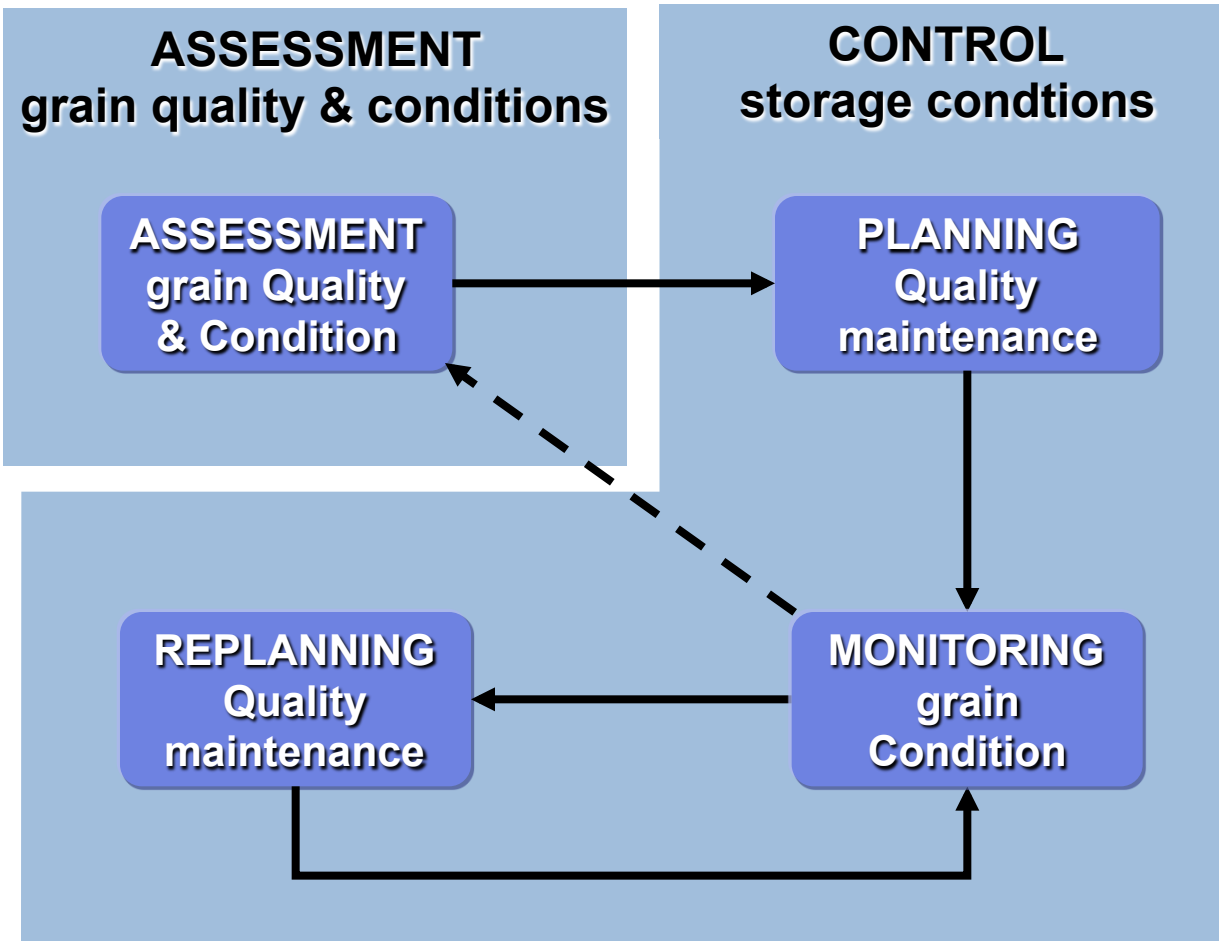
**Système expert de gestion de la qualité de l'orge
de brasserie stockée**

Amadou Ndiaye

INRA

France

Preventive strategy



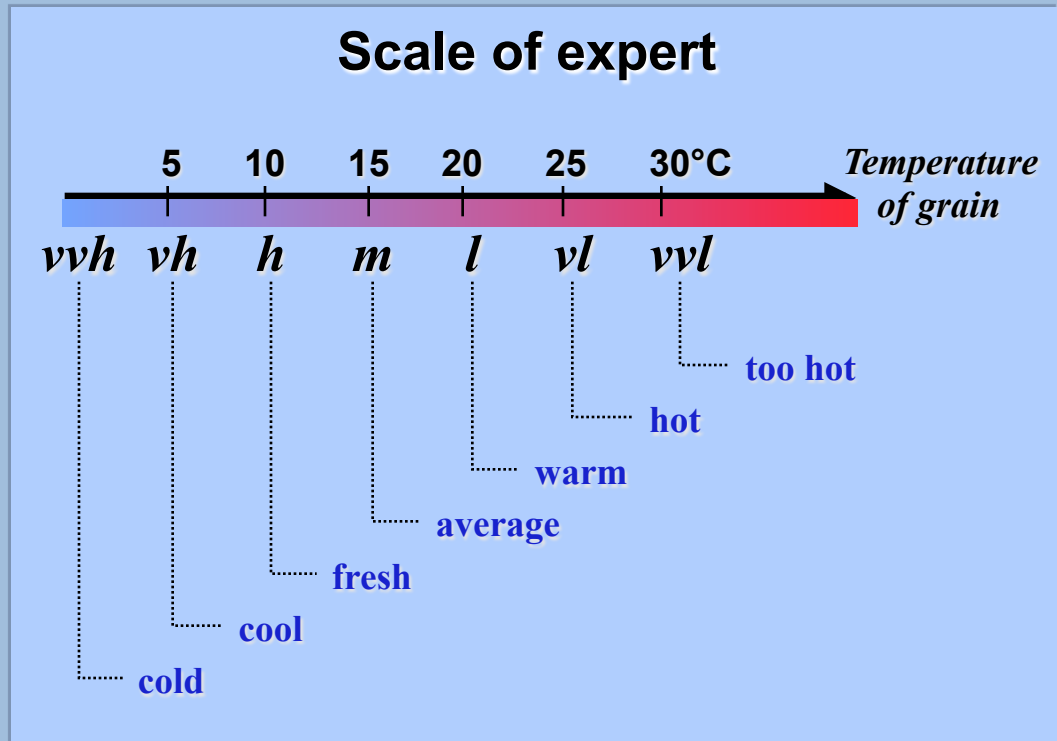
Quality



f(Physico-chemical Characteristics,
Sanitary-Safety characteristics,
Technological potential,
Nutritional potential)

Assessment of Grain Quality

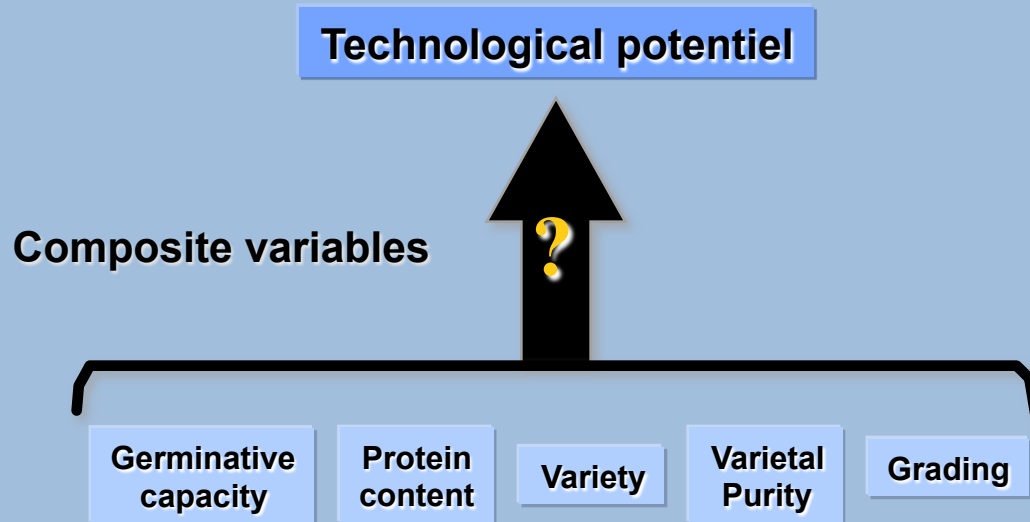
Grain Quality Space



- 7 elements symbolic space
 $\{vvl, vl, l, m, h, vh, vvh\}$
- Ordered space
 $vvl < vl < l < m < h < vh < vvh$
- 2 basic functions *pred* and *suc*
 $pred(m) = h, \quad pred(vvh) = vvh$
 $suc(m) = l, \quad suc(vvl) = vvl$
 $pred(suc(m)) = suc(pred(m)) = m$
 $pred(pred(m)) = vh, \quad suc(suc(m)) = vl$
- 3 comparison operators
eq, gt, lt
- 4 composing operators
min, max, min-max, max-min
 $min(x,y)=x \Leftrightarrow x \text{ lt } y$
 $max(x,y)=x \Leftrightarrow x \text{ gt } y$
- *Ad-hoc* operators
 $\alpha, \beta \dots$

Assessment of Grain Quality

Human experts cognitive operations

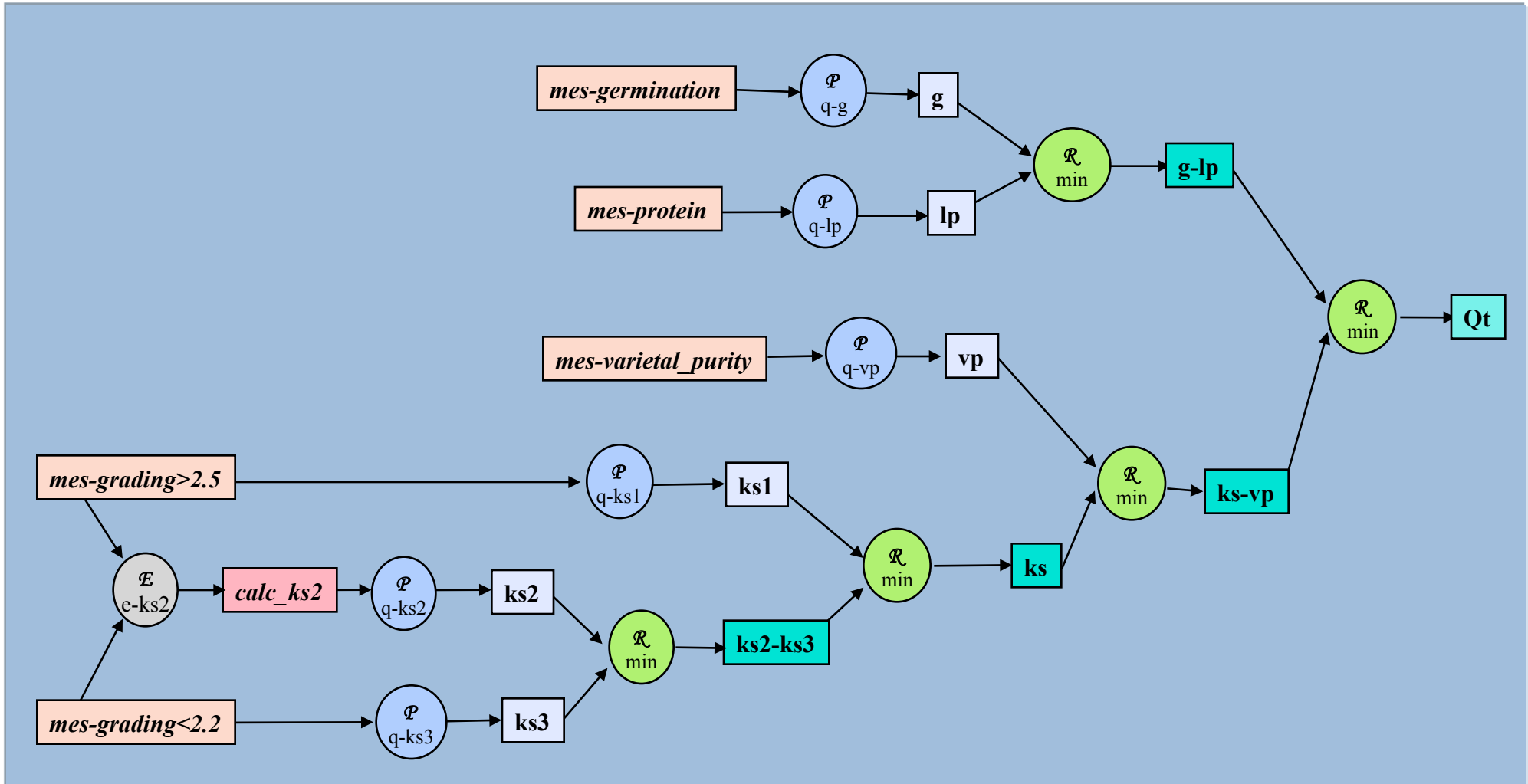


7 Abstracts operations

- Projection (\mathcal{P}_j)
 $\mathcal{P}_j : R \rightarrow Q$ or $V \rightarrow Q$
- Reduction (\mathcal{R})
 $\mathcal{R} : Q \times Q \rightarrow Q$
- Deduction (\mathcal{D})
 $\mathcal{D} : Q \times Q \rightarrow Q$ or $Q \rightarrow Q$
or $Q \rightarrow V$ or $V \rightarrow V$
or $V \times V \rightarrow R$
- Induction (I)
 $I : Q \rightarrow Q$
- Prediction (\mathcal{P})
 $\mathcal{P} : R \rightarrow Q$ or $R \times R \rightarrow Q$
- Critic (C)
 $C : Q \rightarrow V$ or $Q \times Q \rightarrow V$
- Equation (\mathcal{E})
 $\mathcal{E} : R^n \rightarrow R$ with $n > 0$

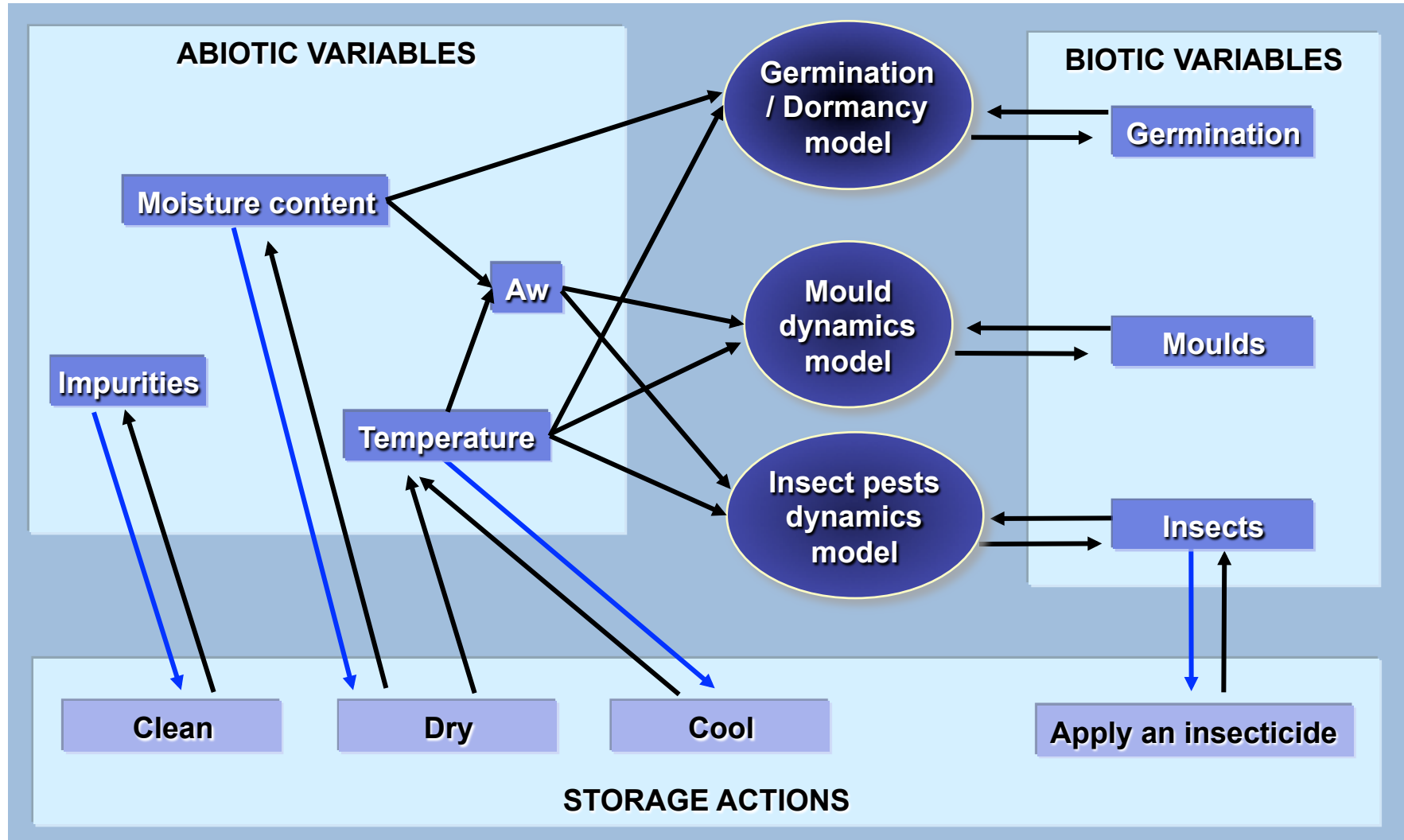
Assessment of Grain Quality

Technological potential



Control of storage conditions

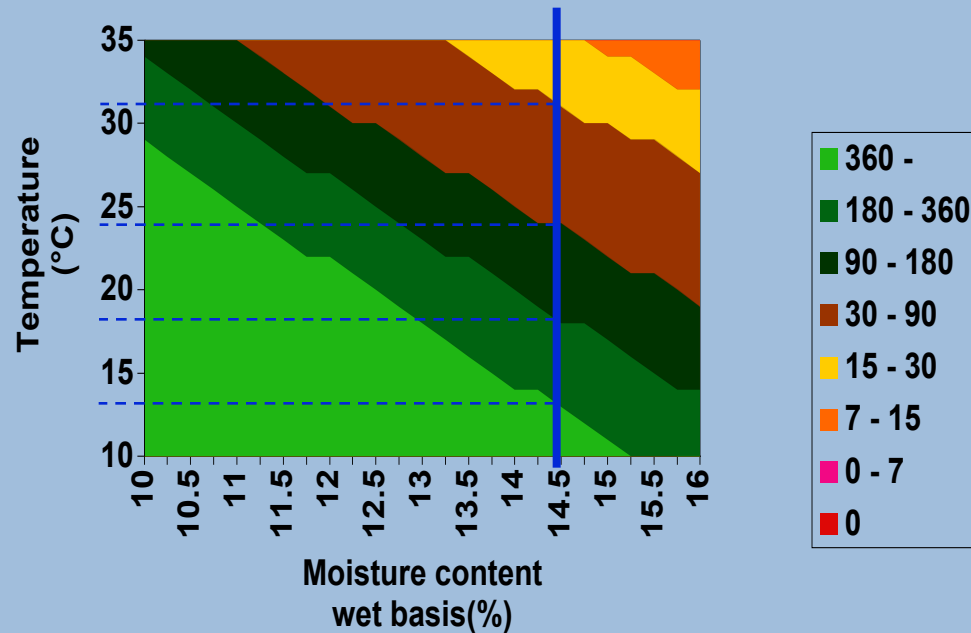
Planning of quality maintenance



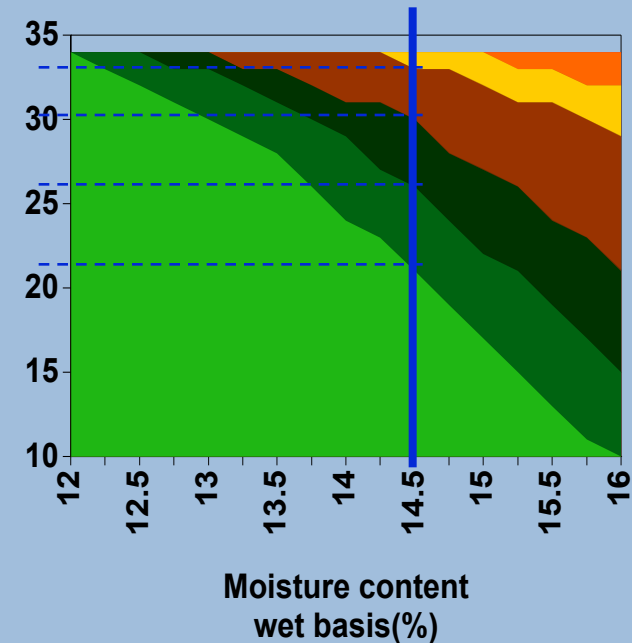
Control of storage conditions

Stability zone: Monitoring of grain condition

Germinative capacity decrease to 95%

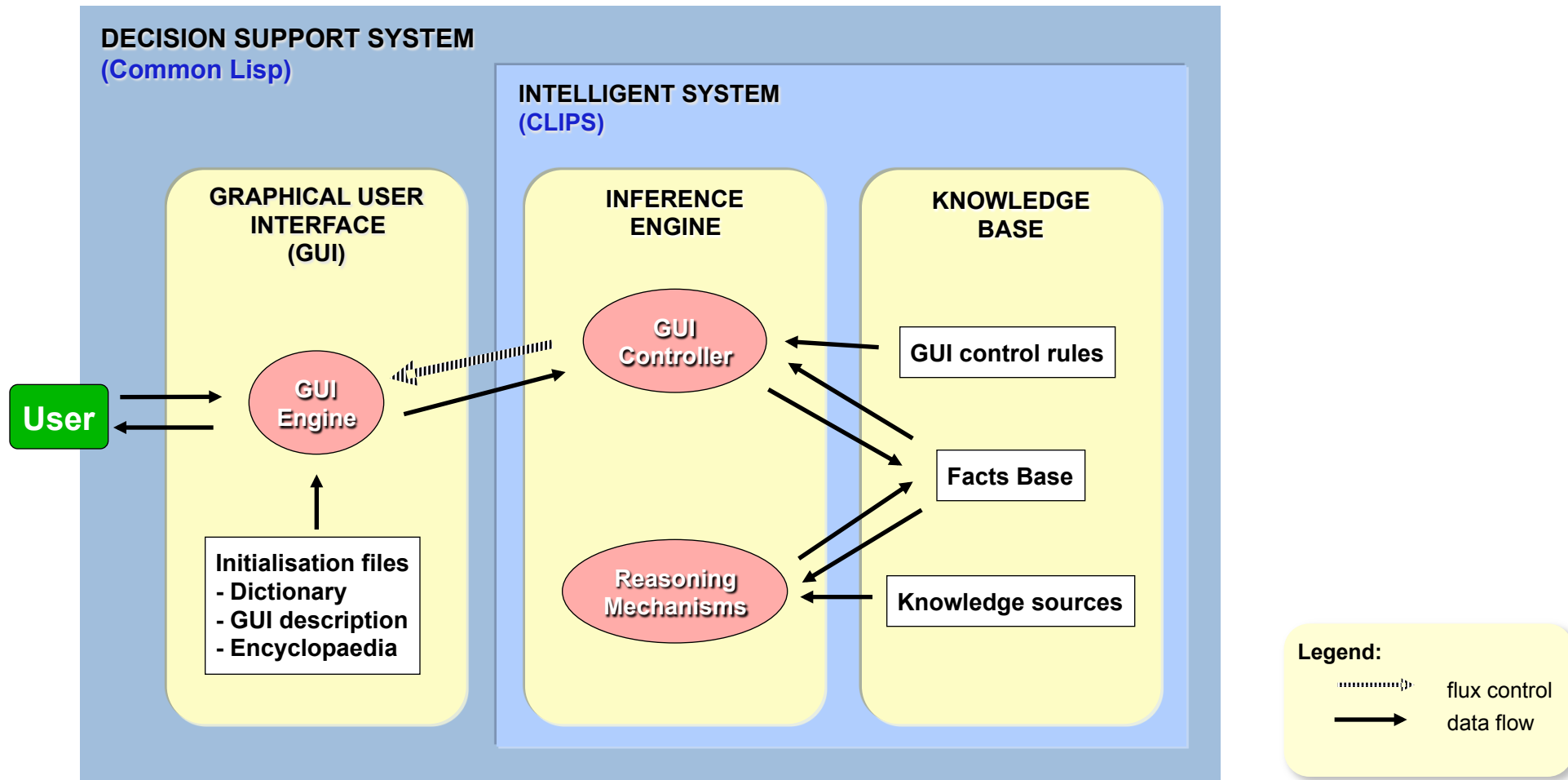


Spoilage by moulds



Implementation

Flexible modular architecture



Input of raw data

Qualis
FILE HELP-MENU

Input of raw data at the harvest

Physico-chemical characteristics

Temperature (°C)

Moisture content (%)

Impurities

Total impurities (%)

Broken grain (%)

Technological characteristics

Germinative energy (%)

Level of protein (%)

Tetrazolium (%)

Varietal purity (%)

Varietu of barleu

Sanitary and safety characteristics

Free living insects (/kg)

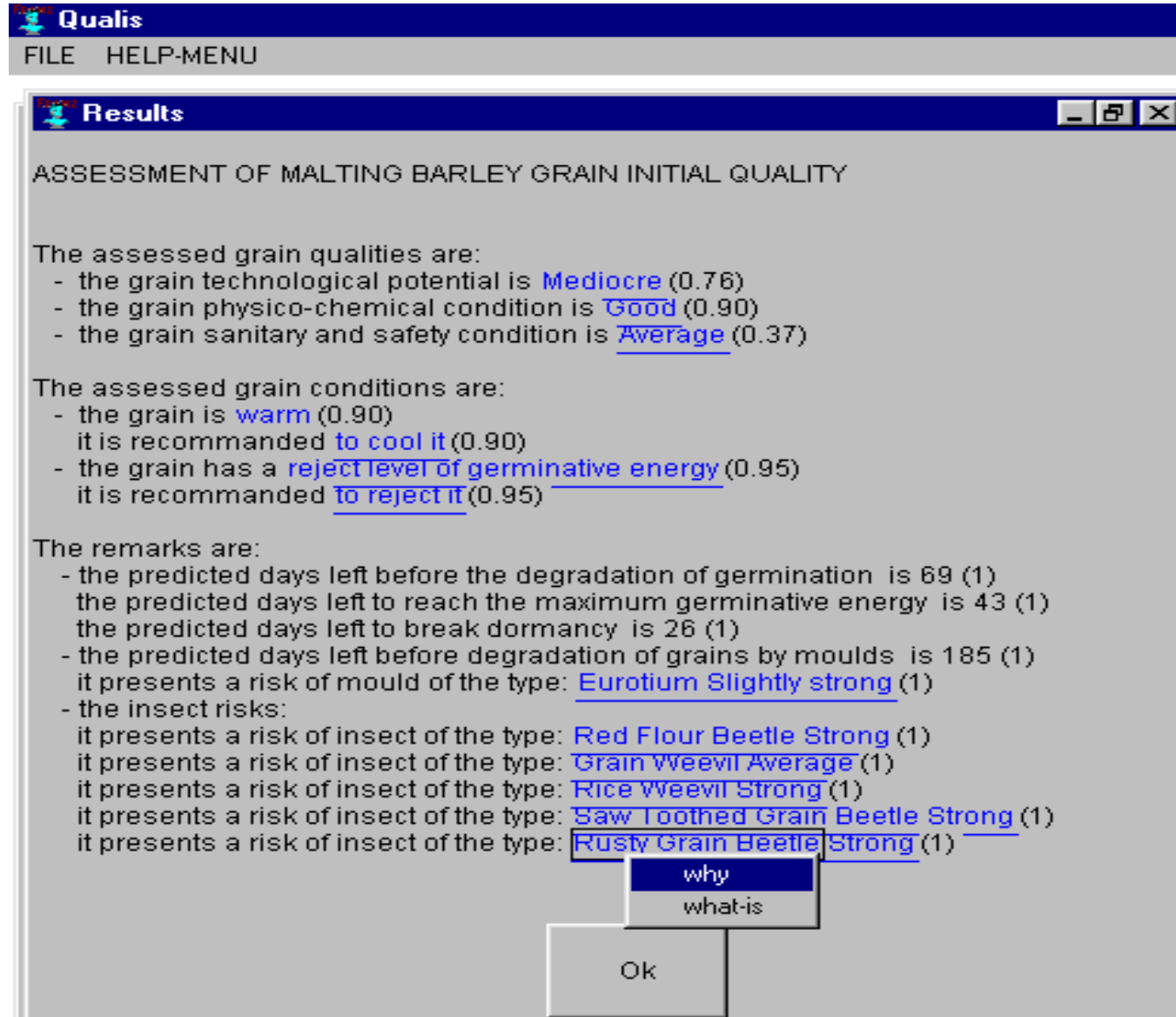
Free dead insects (/kg)

Hidden form of insects (/kg)

Level of ergosterol (µg/g)

Quantity (t)

Assessment of malting barley quality and condition



Qualis
FILE HELP-MENU

Results

ASSESSMENT OF MALTING BARLEY GRAIN INITIAL QUALITY

The assessed grain qualities are:

- the grain technological potential is **Mediocre** (0.76)
- the grain physico-chemical condition is **Good** (0.90)
- the grain sanitary and safety condition is **Average** (0.37)

The assessed grain conditions are:

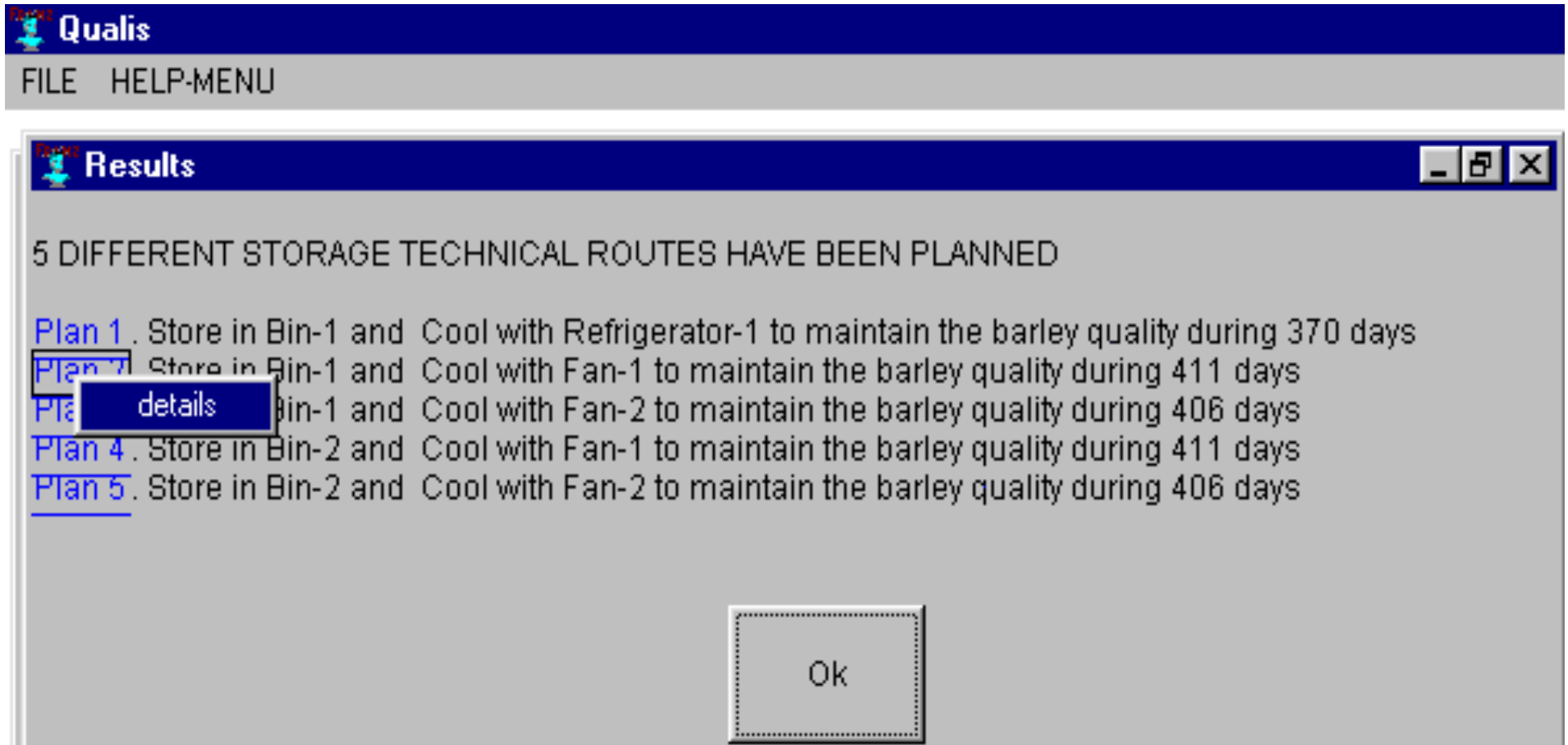
- the grain is **warm** (0.90)
it is recommended **to cool it** (0.90)
- the grain has a **reject level of germinative energy** (0.95)
it is recommended **to reject it** (0.95)

The remarks are:

- the predicted days left before the degradation of germination is 69 (1)
the predicted days left to reach the maximum germinative energy is 43 (1)
the predicted days left to break dormancy is 26 (1)
- the predicted days left before degradation of grains by moulds is 185 (1)
it presents a risk of mould of the type: **Eurotium Slightly strong** (1)
- the insect risks:
it presents a risk of insect of the type: **Red Flour Beetle Strong** (1)
it presents a risk of insect of the type: **Grain Weevil Average** (1)
it presents a risk of insect of the type: **Rice Weevil Strong** (1)
it presents a risk of insect of the type: **Saw Toothed Grain Beetle Strong** (1)
it presents a risk of insect of the type: **Rusty Grain Beetle Strong** (1)

why
what-is
Ok

The optimal storage technical routes



The screenshot shows a software window titled "Qualis" with a menu bar containing "FILE" and "HELP-MENU". Inside the window is a sub-window titled "Results" with standard window controls (minimize, maximize, close). The main content of the "Results" window is as follows:

5 DIFFERENT STORAGE TECHNICAL ROUTES HAVE BEEN PLANNED

- [Plan 1](#) . Store in Bin-1 and Cool with Refrigerator-1 to maintain the barley quality during 370 days
- [Plan 2](#) . Store in Bin-1 and Cool with Fan-1 to maintain the barley quality during 411 days
- [Plan 3](#) **details** . Store in Bin-1 and Cool with Fan-2 to maintain the barley quality during 406 days
- [Plan 4](#) . Store in Bin-2 and Cool with Fan-1 to maintain the barley quality during 411 days
- [Plan 5](#) . Store in Bin-2 and Cool with Fan-2 to maintain the barley quality during 406 days

At the bottom center of the window is an "Ok" button.

The detail of the PLAN 2

Qualis
FILE HELP-MENU

Results

PLAN 2

2 storage operations to carry out during 48 days to maintain the barley quality during 411 days

Initial grain condition:
 germinative capacity 80%, temperature 25°C, moisture content 14.50%, activity of water 0.73,
 level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
 The estimated safe storage periodes in the same grain condition are 69 days for the germinative capacity,
 26 days for the dormancy break, 43 days for the maximum germinative energy and 185 days for the moulds

1. Store grain in the vertical bin Bin-1
 Grain condition:
 germinative capacity 80%, temperature 25°C, moisture content 14.50%, activity of water 0.73,
 level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
 The estimated safe storage periodes in the same grain condition are 69 days for the germinative capacity,
 26 days for the dormancy break, 43 days for the maximum germinative energy and 185 days for the moulds
2. Cool grain using the fan Fan-1 in 3 steps to reach 10°C of temperature in 48 days for an estimated period of 228 days
 - Step 1 to reach 22°C of temperature in 4 days for an estimated period of 180 days
 The estimated safe storage periodes in the same grain condition are 104 days for germinative capacity,
 31 days for dormancy break, 59 days for maximum germinative energy and 284 days for moulds
 - Step 2 to reach 15°C of temperature in 18 days for an estimated period of 180 days
 The estimated safe storage periodes in the same grain condition are 257 days for germinative capacity,
 21 days for dormancy break, 104 days for maximum germinative energy and 690 days for moulds
 - Step 3 to reach 10°C of temperature in 26 days for an estimated period of 180 days

Grain condition:
 germinative capacity 96.99%, temperature 10°C, moisture content 14.50%, activity of water 0.70,
 level of impurities 2.00%, free living insects 0/kg, free dead insects 0/kg, insecticide none
 The estimated safe storage periodes in the same grain condition are 460 days for the germinative capacity,
 0 days for the dormancy break, 138 days for the maximum germinative energy and 1309 days for the moulds

=> IT IS RECOMMANDED TO CONTROL THE PRESENCE OF INSECTS IN 411 DAYS

 THE DELAY NECESSARY FOR A SUFFICIENT DECREASING OF THE TEMPERATURE BETWEEN
 TWO COOLING AERATION STEPS IS NOT ACCOUNTED FOR IN THIS DEMO VERSION

Ok

The detail of the PLAN 2

PLAN 2

2 storage operations to carry out during 48 days to maintain the barley quality during 411 days

Initial grain condition: GermC 80%, T 25°C, mc 14.50%, Aw 0.73, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

Germinative capacity 69d and Moulds 185d (DormB 26d, maxGermC 43d)

1. Store grain in the vertical bin Bin-1

Grain condition: GermC 80%, T 25°C, mc 14.50%, Aw 0.73, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

Germinative capacity 69d and Moulds 185d (DormB 26d, maxGermC 43d)

The detail of the PLAN 2

2. Cool grain using the fan Fan-1 in 3 steps to reach 10°C of temperature in 48 days for an estimated period of 228 days

Step 1 to reach 22°C of temperature in 4 days for an estimated period of 180 days

The estimated safe storage periodes in the same grain condition are

Germinative capacity 104d and Moulds 284d (DormB 31d, maxGermC 59d)

Step 2 to reach 15°C of temperature in 18 days for an estimated period of 180 days

The estimated safe storage periodes in the same grain condition are

Germinative capacity 257d and Moulds 690d (DormB 21d, maxGermC 104d)

Step 3 to reach 10°C of temperature in 26 days for an estimated period of 180 days

Grain condition: GermC 96.99%, T 10°C, mc 14.5%, Aw 0.7, Imp 2%, insect 0/kg

The estimated safe storage periodes in the same grain condition are

Germinative capacity 460d and Moulds 1309d (DormB 0d, maxGermC 138d)

=> IT IS RECOMMENDED TO CONTROL THE PRESENCE OF INSECTS IN 411 DAYS

The delay necessary for a sufficient decreasing of the temperature between two cooling aeration steps is not accounted for in this demo version

Conclusions

- ⇒ Representation of a heterogeneous complex system
- ⇒ Mixed quantitative and qualitative reasoning
- ⇒ Integration of mathematics models and expert knowledge
- ⇒ Integration of time
- ⇒ Implementation of a prototype on a PC computer: *QualiS*©
- ⇒ Validation by the experts
- ⇒ Validation in pilot scale experiments 10 tons (DK) & 20 tons (UK)

Prediction of the duration of cooling aeration and its effects to refine

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