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# Heterogeneity of residual variances of milk fatty acids in dairy cattle

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# Collaborations

- CRA-W
  - Frédéric Dehareng – Pierre Dardenne
- Comité du Lait
  - Didier Veselko – Emile Piraux
- AWE
  - Carlo Bertozzi – Laurent Laloux

# Context

- Routine genetic evaluation for milk fatty acids is under development in the Walloon Region of Belgium

- The model used in genetic evaluations is a multi-trait random regression test-day model (RRTDM) (Auvray and Gengler, 2002)

# Context

- Genetic evaluation model

$$y=X_t t+Q(W_t h+Z_t g+Z_t p)+e$$

**Fixed effects :**

- herd * test date
- stage of lactation
- gestation stage
- lactation stage*calving season*breed*calving period regressed on age at calving

# Context

- Genetic evaluation model

$$y = X_t t + Q(W_t h + Z_t g + Z_t p) + e$$

**Random regression effects :**

- herd × period of calving
- additive genetic
- permanent environmental

**Random residuals**

# Context

- Genetic evaluation model

$$y = X_t t + Q(W_t h + Z_t g + Z_t p) + e$$

**Matrices :**

- **X, W, Z** are incidence matrices,
- **Q** is the covariate matrix for the second order Legendre polynomials.

# Context

- ***Accuracy of estimated breeding values is one major component in designing breeding programs***
- In mixed models, it is often assumed that the residual variance is the same for all observations (Rönnegard et al., 2010)
- BUT: variation of the residual variances seems to be quite common
- BUT: Assuming a homogeneous residual variance could affect the genetic evaluation (Takma, 2009)
- → so, it could be important to include the heterogeneity of residual variance in the used model

# General objective

***To test the heterogeneity of residual variances*** for

- Milk, fat and protein yields
- Monounsaturated and saturated fatty acids

→Indirectly, to study the goodness of fit of the model (average residuals)

# Materials & Methods

- Dataset
  - –First lactation
  - –Traits involved in the genetic evaluation :

    Milk, fat and protein yields (kg/day)

    (Milk, qFAT and qPROT)

    → +/- 6,687,000 records
  - –Traits not involved in the genetic evaluation : content of saturated and monounsaturated fatty acids in milk (g/dl of milk)

    (SAT and MONO)

    → +/- 220,000 records

# Materials & Methods

- Residuals:
  - ➔ Observed values – Estimated values
- Squared residuals ≈ residual variance
- Studied effects are:
  - –The month of test date
  - –The calving month
  - –The year of test date
  - –The age at calving
  - –And the stage of lactation

# Studied traits

| Trait | N | Mean | SD |
|---|---|---|---|
| **MILK (kg/day)** | 6,749,239 | 16.96 | 6.83 |
| **qFAT (kg/day)** | 6,746,993 | 0.68 | 0.29 |
| **qPROT (kg/day)** | 6,727,524 | 0.56 | 0.22 |
| **SAT (%)** | 220,397 | 2.79 | 0.49 |
| **MONO (%)** | 220,396 | 1.15 | 0.24 |

# Residuals

| Trait | N | Mean | SD |
|---|---|---|---|
| **MILK (kg/day)** | 6,749,239 | 0.00 | 1.35 |
| **qFAT (kg/day)** | 6,746,993 | 0.00 | 0.07 |
| **qPROT (kg/day)** | 6,727,524 | 0.00 | 0.05 |
| **SAT (%)** | 220,397 | 0.00 | 0.17 |
| **MONO (%)** | 220,396 | 0.00 | 0.09 |

# Results --- Squared residuals

| Trait | N | Mean | SD |
|---|---|---|---|
| **MILK ($kg^2/day^2$)** | 6,749,239 | 1.821 | 9.774 |
| **qFAT ($kg^2/day^2$)** | 6,746,993 | 0.0051 | 0.0208 |
| **qPROT ($kg^2/day^2$)** | 6,727,524 | 0.0023 | 0.0120 |
| **SAT ($\%^2$)** | 220,397 | 0.0276 | 0.0615 |
| **MONO ($\%^2$)** | 220,396 | 0.0089 | 0.0218 |

# Results --- Month of test-date

| P value | Month of test date |
|---|---|
| Milk | *** |
| qFAT | *** |
| qPROT | *** |
| SAT | *** |
| MONO | *** |

The effect of month of test date on squared residuals is highly significant for all traits

# Results --- Month of test-date

- Peak during the spring (April → June)
- Lowest values during the summer
- Similar trend for milk, fat and protein yields and for SAT vs MONO (smoother)

# Results --- Calving month

| P value | Calving month |
|---|---|
| Milk | *** |
| qFAT | *** |
| qPROT | *** |
| SAT | *** |
| MONO | *** |

The effect of calving month on squared residuals is highly significant for all traits

# Results --- Month of test-date

- Peak in August
- Lowest values during the spring (April → June)
  - Vs Month of calving effect
- Similar trend for milk, fat and protein yields vs for SAT and MONO (smoother)

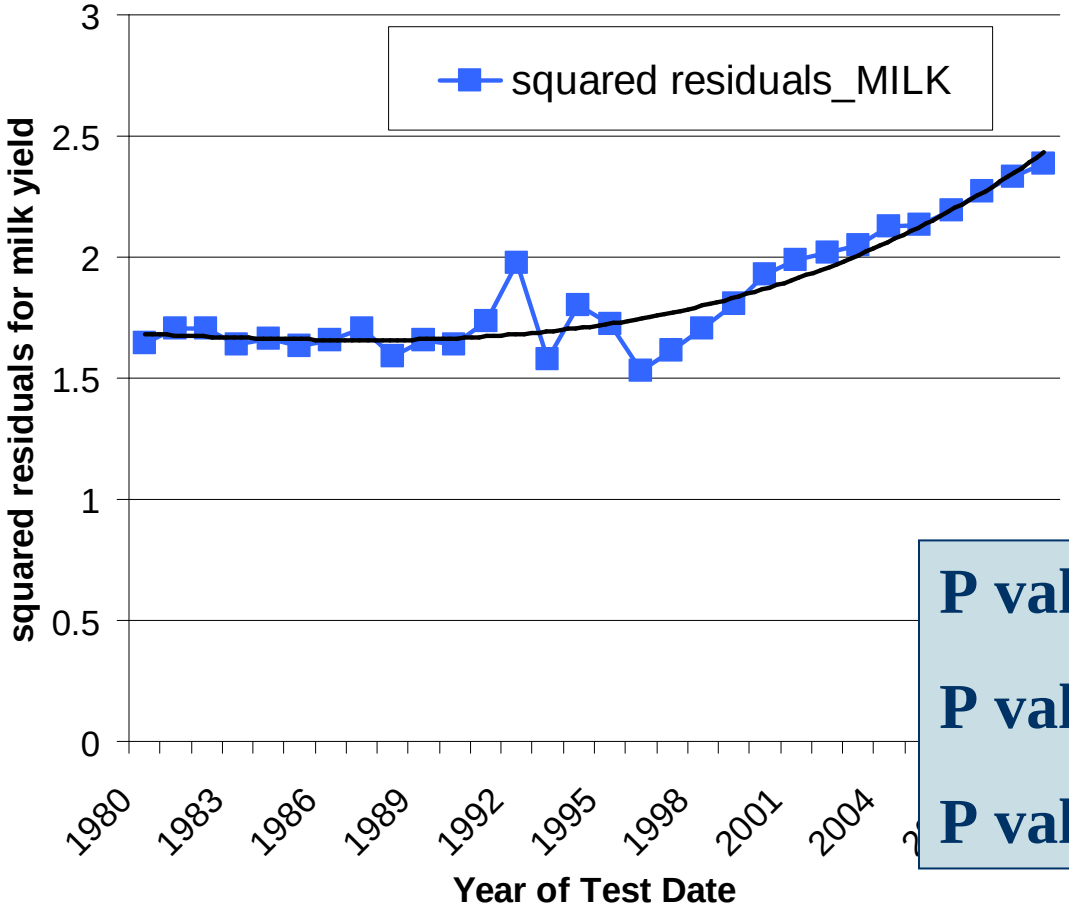
# Results --- Year of test date

| P value | Year of test date |
|---|---|
| Milk | *** |
| qFAT | *** |
| qPROT | *** |

The effect of year of test date on squared residuals is highly significant for milk, fat and protein yields

# Results --- Year of test date

Trend of squared residuals for milk yield according to year of test date



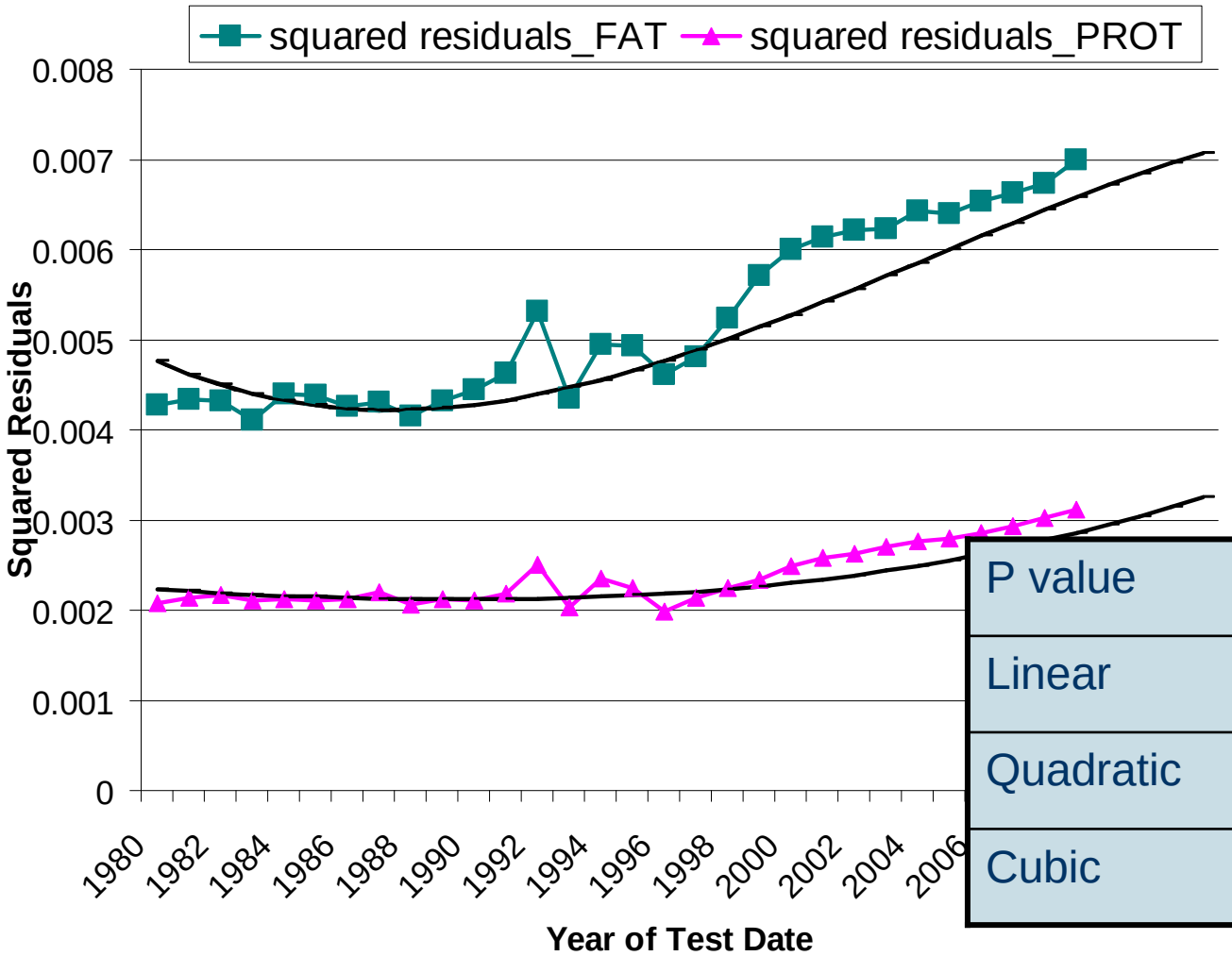

**P value Linear: *****

**P value Quadratic: *****

**P value Cubic: *****

# Results --- Year of test date

Trend of squared residuals for fat and protein yields according to year of test date




| P value | FAT | PROT |
|---|---|---|
| Linear | *** | *** |
| Quadratic | *** | *** |
| Cubic | *** | *** |

# Results --- Age at calving

| P value | Age at calving |
|---|---|
| Milk | NS |
| qFAT | NS |
| qPROT | NS |
| SAT | NS |
| MONO | NS |

The effect of age at calving on squared residuals is not significant for any traits

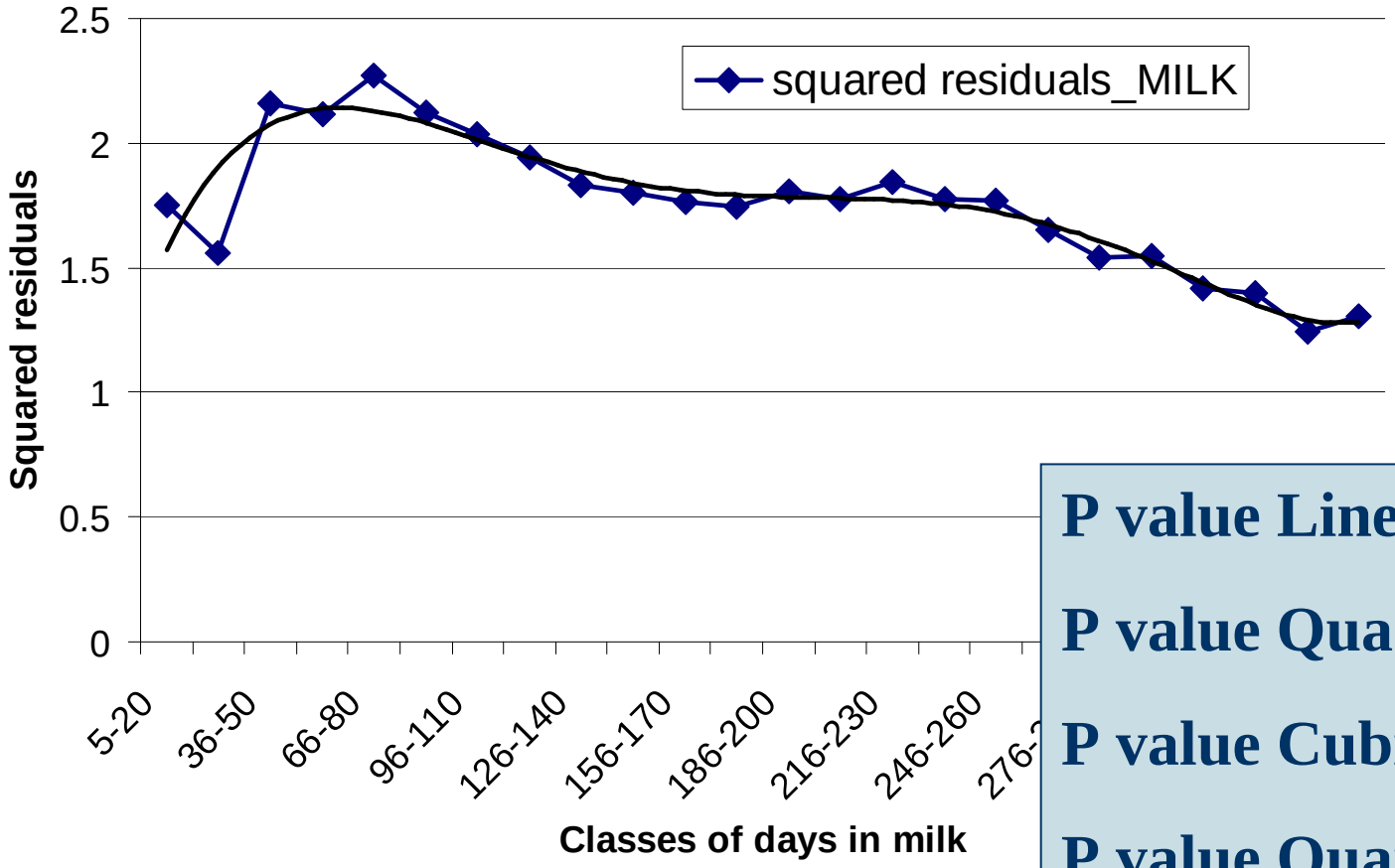
# Results --- Stage of lactation

| P value | DIM |
|---|---|
| Milk | *** |
| qFAT | *** |
| qPROT | *** |
| SAT | *** |
| MONO | *** |

The effect of stage of lactation on squared residuals is highly significant for all traits

# Results --- Stage of lactation

Trend of squared residuals for milk yield according to the stage of lactation




**P value Linear: ***

**P value Quadratic: ***

**P value Cubic: ***

**P value Quartic: ***

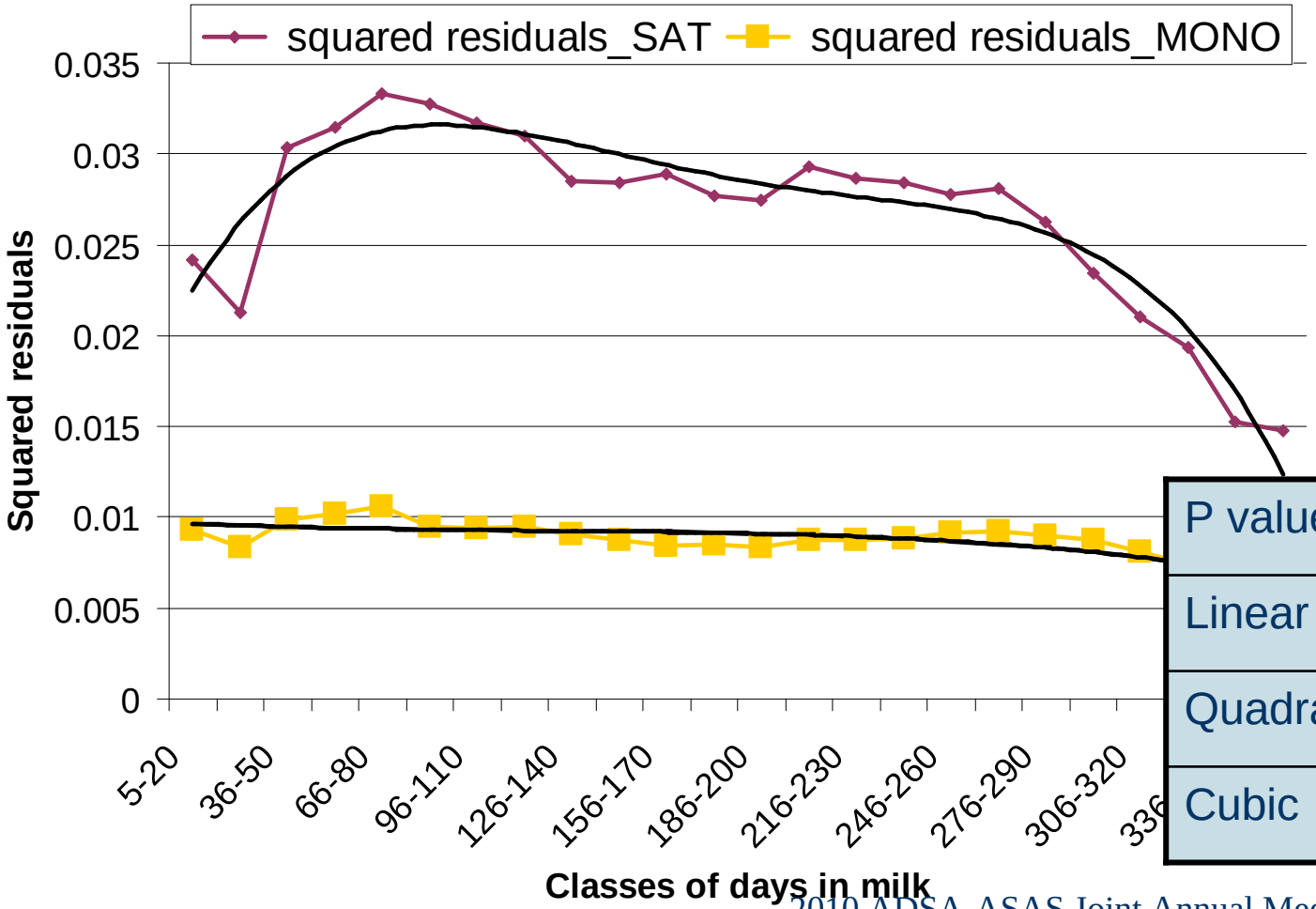
# Results --- Stage of lactation

Trend of squared residuals for fat and protein yields according to the stage of lactation


| P value | FAT | PROT |
|---|---|---|
| Linear | *** | *** |
| Quadratic | *** | *** |
| Cubic | *** | *** |
| Quartic | *** | *** |

# Results --- Stage of lactation

Trend of squared residuals for SAT and MONO according to the stage of lactation




| P value | SAT | MONO |
|---|---|---|
| Linear | *** | NS |
| Quadratic | *** | * |
| Cubic | * | ** |

# Conclusions

- Means of residuals were stable and close to zero for all traits

- Trends of squared residuals: differences between milk, fat and protein yields and SAT and MONO

- → Introduction of heterogeneous residual variance could be interesting for the accurate model definition

# Conclusions

- How to introduce this heterogeneity?

- Suggestion : introduction of correction of variability of squared variances according to stages of lactation

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