Relationship between feed ingredient properties and pellet quality

PREDICTIVE MODELS BASED ON PRODUCTION DATA.

Dr. MSc Mia Eeckhout
Content

1. Introduction
2. Water Absorption Index
3. Data collection and statistics
4. Results and Discussion
Low Cost Formulation

- Raw materials availability and price
- Technology
- Farmer demands
- Nutritional science
- Environment
- Politics
- Animal Health
- Commercial issues

Compound Feed
Raw material

- Availability and price
- Price sensitiveness of compound feed
- Price stress on animal product
Pellet quality depends on:

- 40% formulation
- 20% particle size
- 20% conditioning
- 15% die choice
- 5% cooler

Pellet mill operator meets problems
Low pellet quality

- Product losses
- Decreased feed intake
- Dust in feeding device
- Complaints → client loss
- Binders?
Quality of 4 mm pig feed pellet

QUALITY = OK

WARNING

ACTION

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Formula change

End quality change
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Water absorption index

Feed tends to adsorb water
pos → NSP – fibre
Neg → fat content

Experimental value
Influence binding of pellets
Easy to determine

<table>
<thead>
<tr>
<th>Raw material</th>
<th>WI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>3,07</td>
</tr>
<tr>
<td>Corn</td>
<td>2,46</td>
</tr>
<tr>
<td>Wheat</td>
<td>2,47</td>
</tr>
<tr>
<td>Wheat tailings</td>
<td>4,45</td>
</tr>
<tr>
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<td>3,86</td>
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<td>byproducts bakery</td>
<td>3,71</td>
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<td>Corn middling</td>
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<tr>
<td>Corn germ meal</td>
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<tr>
<td>Rapeseed meal.</td>
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</tr>
<tr>
<td>Toasted soy bean</td>
<td>2,30</td>
</tr>
<tr>
<td>Soy meal</td>
<td>3,97</td>
</tr>
<tr>
<td>Sunflour meal</td>
<td>3,63</td>
</tr>
<tr>
<td>Chalk</td>
<td>1,12</td>
</tr>
<tr>
<td>Beet root pulp</td>
<td>6,76</td>
</tr>
<tr>
<td>Fat/oil</td>
<td></td>
</tr>
</tbody>
</table>
Non-starch polysaccharides refer to all carbohydrate fractions and types of dietary fiber

- with the exception of lignin (ADL)
- either soluble or insoluble (Capitra, 2010)

The hydration properties of NSP influence its water holding capacity and water binding capacity (Moms, 1992).
Calculated WI of mixtures

$W_I_{\text{theoretical}}$ ( )
Theoretical WI versus experimental

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Data set: Piglet and pig formula produced in 2012-2013 (101)

All raw material data from LP database
Including WI
+ measured Kahl Hardness
+ measured Q-pfost
Data set: technological information

Piglet and pig formula produced in 2012-2013
- Pellet mill with steam conditioning at 60°C (normal conditioning)
- 4 mm die
- No binding agents or pelleting aids used
Statistics

- high-dimensional dataset,
- small number truly informative, while others are redundant
- some are correlated
Statistics: 1\textsuperscript{st} step in predictive modelling

- identifying the truly informative

- **underfitted** model excludes truly informative variables $\rightarrow$ estimation bias in model fitting

- **overfitted** model includes the redundant uninformative variables $\rightarrow$ increases the estimation variance and hinders the model interpretation.
Statistics: Pearson correlation coefficient (R)

- The determination of R is a measure of the linear relation between a predictor variable (x) and a response variable (y) which is calculated as

$$R = \frac{\sum (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \cdot \sum (y_i - \bar{y})^2}}$$
Statistics: modelling techniques

- multiple (stepwise) linear, Lasso, ridge regression and regression trees were compared
- Lasso and ridge regression are regression methods that involve penalizing the absolute size of the regression coefficients.
Statistics: estimate the model performance

Method: cross validation f.e. leave-one-out cross validation

- the cross-validated $R^2 \rightarrow$ as close to 1
- Mean Squared Error (MSE) $\rightarrow$ as close to 0
Content

1. Introduction
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<table>
<thead>
<tr>
<th></th>
<th>Ash</th>
<th>Durability</th>
<th>Hardness</th>
<th>NDF_ADF</th>
<th>NDF</th>
<th>WI</th>
<th>DNSP</th>
<th>NSP</th>
<th>CF</th>
<th>ADF</th>
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<tr>
<td>Ash</td>
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<td>0.53</td>
<td>0.78</td>
<td>-0.21</td>
<td>-0.33</td>
<td>-0.48</td>
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<tr>
<td>Durability</td>
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<td>1</td>
<td>0.78</td>
<td>-0.21</td>
<td>-0.33</td>
<td>-0.48</td>
<td>-0.38</td>
<td>-0.35</td>
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<td>-0.21</td>
<td>-0.21</td>
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<tr>
<td>WI</td>
<td>-0.48</td>
<td>-0.48</td>
<td>-0.48</td>
<td>0.62</td>
<td>0.78</td>
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<td>0.91</td>
<td>0.91</td>
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</tr>
<tr>
<td>DNSP</td>
<td>-0.48</td>
<td>-0.48</td>
<td>-0.48</td>
<td>0.62</td>
<td>0.78</td>
<td>0.91</td>
<td>1</td>
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<tr>
<td>NSP</td>
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<td>-0.38</td>
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<td>0.78</td>
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<tr>
<td>CF</td>
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<tr>
<td>ADF</td>
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<td>0.78</td>
<td>0.78</td>
<td>0.78</td>
<td>0.78</td>
<td>1</td>
</tr>
</tbody>
</table>

- ADF: Ash Digestible Fiber
- CF: Crude Fiber
- NSP: Non-starch Polysaccharides
- DNSP: Dietary Non-starch Polysaccharides
- WI: Water Insoluble
- NDF: Neutral Detergent Fiber
- NDF_ADF: Neutral Detergent Fiber - Ash Digestible Fiber
<table>
<thead>
<tr>
<th>Model type</th>
<th>KHD</th>
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<tbody>
<tr>
<td>linear</td>
<td>$6.95 - 0.51 \times \text{fat} + 0.65 \times \text{WI}$</td>
</tr>
<tr>
<td>Lasso</td>
<td>$6.94 - 0.50 \times \text{fat} + 0.64 \times \text{WI}$</td>
</tr>
<tr>
<td>Ridge</td>
<td>$6.98 - 0.48 \times \text{fat} + 0.60 \times \text{WI}$</td>
</tr>
<tr>
<td>Model</td>
<td>MSE (CV)</td>
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<tr>
<td>---------------------</td>
<td>----------</td>
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<tr>
<td>Linear regression</td>
<td>0.101</td>
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<tr>
<td>Lin. Reg. (fat, WI)</td>
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<tr>
<td>LASSO</td>
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<tr>
<td>LASSO (fat, WI)</td>
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<tr>
<td>Ridge</td>
<td>0.099</td>
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<tr>
<td>Ridge (fat, WI)</td>
<td>0.089</td>
</tr>
</tbody>
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Conclusions on Hardness

all modelling techniques resulted in comparable $R^2$ and MSE predictive model for hardness based on two parameters: fat percentage and WI with $R^2 = 0.82$ and a MSE of 0.088 (multiple linear)
<table>
<thead>
<tr>
<th>Model type</th>
<th>Q-pfost durability</th>
</tr>
</thead>
<tbody>
<tr>
<td>linear</td>
<td>$97.22 - 0.38 \times \text{fat} + 0.395 \times \text{WI}$</td>
</tr>
<tr>
<td>Lasso</td>
<td>$97.16 - 0.35 \times \text{fat} + 0.37 \times \text{WI}$</td>
</tr>
<tr>
<td>Ridge</td>
<td>$97.22 - 0.37 \times \text{vet} + 0.37 \times \text{WI}$</td>
</tr>
</tbody>
</table>
Conclusions on Durability (Q-pfost)
correlation were found to be much lower
pellet durability more difficult to predict
lower $R^2$ and a higher MSE for all models
The final (best) model was based on the components
fat, WI, sugar and ADL with a cross-validated $R^2$ of 0.60 and a MSE of 0.120.
Lab pellet quality versus predicted

1) 3 Pig/piglet formula (small piglets, piglets, pigs)

2) Ruminant feed (16 formulas) – similar statistics based on production data
Predicted and experimental (lab scale) data for piglet/pig formula
Overall conclusion for feed producers

Based on production data and trend analysis predict the influence of feed raw material choice related to pellet quality

Add supplementary restrictions to the use of RM if pellet quality tends to go below limits
With special thanks to:

Msc P. Gouwy – the nutritionist from VDA – Ooigem

Msc Sofie Landschoot – with the best statistical skills ever

Msc Sigrid Van Geyte (assistant) for database handling and lab experiments

Marina and Yvan – the best hard working lab technicians

THANK YOU

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