PE4.97 Prediction of yield, colour and texture of comminuted pork products 352.00

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Abstract: The meat processing industry uses various raw materials in the production of comminuted, emulsified meat products. The recipes are typically optimized according to the lowest possible price on raw materials. There is an increased consumer driven demand for so called 'clean label' products with a minimal content of additives. The less additives used, the more important is the functional properties of the meat/fat raw materials used. The aim of this work is to develop a tool that the processing industry can use to predict yield and final product quality of a product on the basis of raw material characteristics and the recipe composition. Predictive models for gel separation, fat separation, total separation, breaking strength and colour have been derived. The models for breaking strength and colour have R2>0.94 which is considered adequate for industrial use. The model for gel separation has R2=0.83. The models for fat separation and total separation have R2 = 0.75 and 0.64 respectively, which are relatively low. However, as the alternative to these low R2 is no model at all, they might prove useful as a working tool until better predictions can be found.

Index Terms - Meat products, Predictive modelling, PLS, Quality and yield.

I. INTRODUCTION

The meat processing industry uses various raw materials of meat and fat in the production of comminuted, emulsified meat products like frankfurter sausage and saveloy. The recipes are typically optimized according to the lowest possible price on raw materials and to some extent the final product quality. Least cost formulation programmes have been used in the industry for the last three decades; however, tools to optimize recipes according to final product quality and yield are lacking. The composition of comminuted, emulsified meat products is basically emulsified fat and fat tissue particles fixated in a matrix of protein gels formed by salt soluble proteins and collagen. The fat is emulsified by salt soluble proteins. Various additives like hydrocolloids, non-meat proteins and phosphates are typically added to increase product stability and yield. The use of additives makes it possible to produce highly stable products with a minimal separation of fat and gel, and with a uniform texture almost independently of the raw materials used. There is an increased consumer driven demand for products with a minimal content of additives - so called 'clean label' products. The less additives used, the more important is the functional properties of the meat/fat raw materials used, i.e. the content of protein, fat, collagen and water in the recipe along with meat pH, protein solubility and fatty acid composition. Several previous studies have reported the importance of protein, fat, water and collagen content for the final product quality and for gel/fat separation [1-7]. The aim of this work is to develop a tool that the processing industry can use to predict yield and final product quality of a 'clean label' product on the basis of raw material characteristics and the recipe composition.

II. MATERIALS AND METHODS

A. Raw materials, recipes and analysis

As raw materials pork shoulder, shank, chaps and back fat were used. The recipes were based on a saveloy recipe and had a constant level of NaCl, nitrite, ascorbic acid and spices. No other additives were used. 27 recipes were optimized to cover a variation in water/protein ratio (W/P) from 4.5 to 7.5, a fat/protein ratio (F/P) from 0.7 to 3.7 and a collagen content of 1, 2 and 3 %. Meat products were produced in duplicate on two different days and the order of recipes were randomized. The batters were produced in a bowl chopper and stopped into 350 ml cans that were hermetically sealed and afterwards cooked at 80 ºC to a core temperature of 75 ºC. All processing steps, cooking procedure, chilling procedure and storage times and temperatures were standardized. The content of protein, fat, water, collagen and pigment along with pH and fatty acid composition were determined for the raw materials, and breaking strength, colour, gel/fat separation and total separation was determined for the final products.

B. Modelling

An initial data exploration, in the open-source statistical package R, revealed that it was difficult to use ordinary linear regression to solve these problems. Therefore models were developed with PLS regression in Unscrambler, CAMO version 9.2. The PLS regressions were initiated with the x-variables water content, pH of raw materials, protein content, fat content, collagen, iodine value, poly unsaturated fatty acids (PUFA) and pigment. All possible two-factor interactions and square products were initially included. The PLS regressions were conducted with full cross validation with leave-one-out. Less significant variables were gradually removed until a compromise was reached between a low standard error of prediction (SEP) and not having any unexplainable factors in the model.

III. RESULTS AND DISCUSSION

A. Gel/fat/total separation

The fatty acid composition was described by the iodine value (iodine), the content of poly unsaturated fatty acids (PUFA), the content of mono unsaturated fatty acids (MUFA) and the content of saturated fatty acids (SAF). The regressions showed that the MUFA and SAF values could be considered insignificant. The weighted regression coefficients are shown in table 1. Table 1 Predictors ranked according to the importance in PLS regression on gel, fat and total separation. The gel separation is predicted with the highest correlation. The gel separation is very dependent on the fatty acid composition while the fat separation depends primarily on the water and fat content, and the total separation depends on the water, protein and fat composition. pH of the raw materials could be expected to influence the gel separation, and it was included in the models as an initial x-parameter, but discarded later as it contributed with more noise than explanation. The iodine value was initially included in the models, but later left out, as the iodine value is strongly correlated with PUFA, and PUFA proved to be a better predictor. The squared terms for water, fat and PUFA and the interactions between fat and water and between PUFA and water, collagen and protein, respectively, are necessary to know in order to account for the non-linear effects. The predicted versus measured values are shown in diagram 1-3. Diagram 1 Gel separation - predicted vs. measured Diagram 2 Fat separation - predicted vs. measured Diagram 3 Total separation - predicted vs. measured The prediction of fat separation is weak and mainly based on three high values of measured fat separation (Diagram 2). Future work on this might include more precise descriptions of the fatty acids.

B. Breaking strength

The breaking strength depends primarily on the collagen content, and secondary on the content of pigment and protein. The strong relation between collagen and protein, respectively, to breaking strength of the meat product makes sense, as both collagen and myofibrillar proteins are strong gelating agents. Thus, the higher the protein and/or collagen content in the recipe, the higher the breaking strength of the product. However, the importance of the pigment content in the recipe is more difficult to explain. The variation in pigment content is probably related to the muscle fibre distribution in the recipes and as solubility and gel-strength of myofibrillar proteins differ between red and white muscle fibres [], the pigment content is probably a measure for this. The squared terms for water and pigment are necessary to know in order to account for the non-linear effects. Table 2 Predictors ranked according to the importance in PLS regression on breaking strength Diagram 4, Breaking strength - predicted vs. measured

C. Colour

The pigment content of the recipes has a large influence on both the a-value and L-value, but the content of protein, fat and water is also of importance. These relations are expected to influence the colour as meat pigment is red, fat is white and protein makes up the gel-structure of the product. The squared terms for water and the interactions between fat and water are necessary to know in order to account for the non-linear effects. Table 3 Predictors ranked according to the importance in PLS regression with colour L-values and a-values. Diagram 5, L (Lightness) - predicted vs. measured Diagram 6, a (Redness) - predicted vs. measured

IV. CONCLUSION

Predictive models for gel, fat and total separation, breaking strength and colour have been derived. The models for breaking strength and colour have $R2>0.94$ which is considered adequate for industrial use. The model for gel separation has $R2=0.83$. The models for fat separation and total separation have $R2 = 0.75$ and 0.64 respectively, which are relatively low. However, as the alternative to these low R2 is no model at all, they might prove useful as a working tool until better predictions can be found.

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Compound	**Gel separation**	**Fat separation**	**Total separation**
Water	6	1	12
Protein	5		7
Collagen	4		9
Fat		2	10
PUFA	1	3	11
Pigment	9		6
Collagen*PUFA	3		1
Water*PUFA		6	4
Protein*PUFA	7		8
Fat*Water		5	5
Fat*PUFA		8	
Water^2	8	4	3
Fat^2		7	
PUFA^2	2	9	2
Regression Characteristics			
PC	3	2	3
R^2	0.837	0.750	0.651
SEP	1.57	2.40	3.56

Table 1 Predictors ranked according to the importance in PLS regression on gel, fat and total separation.

Compound	**Breaking strength**
Water	5
Protein	4
Collagen	1
Fat	7
PUFA	3
Pigment	2
Protein^2	8
Pigment^2	6
Regression Characteristics	
PC	3
R^2	0.966
SEP	2.39

Table 2 Predictors ranked according to the importance in PLS regression on breaking strength

Compound	**L, Colour lightness**	**a, Colour redness**
Water	7	6
Protein	2	4
Collagen	3	2
Fat	4	5
PUFA	8	
Pigment	1	1
Fat*Water	6	3
Water^2	5	
Regression Characteristics		
PC	2	3
R^2	0.945	0.945
SEP	0.42	0.20

Table 3 Predictors ranked according to the importance in PLS regression with colour L-values and a-values.

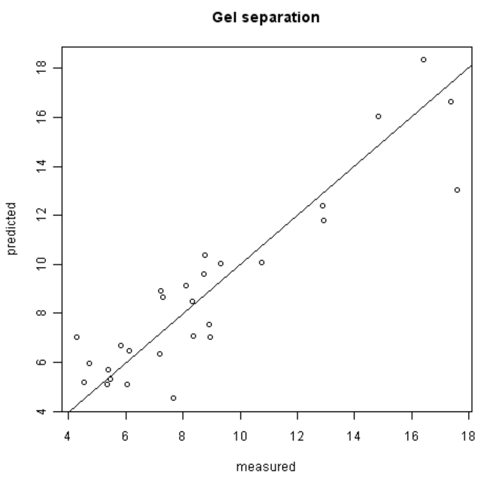

Diagram 1 Gel separation - predicted vs. measured

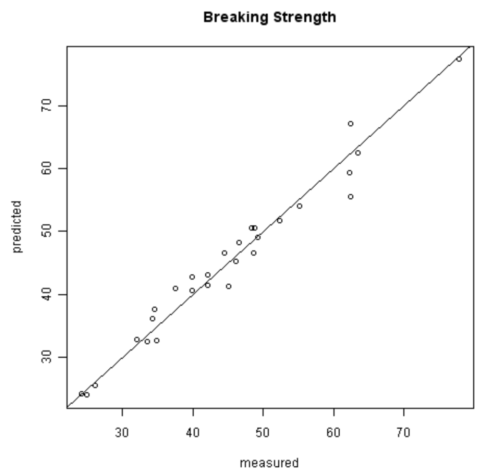

Diagram 2, Breaking strength - predicted vs. measured

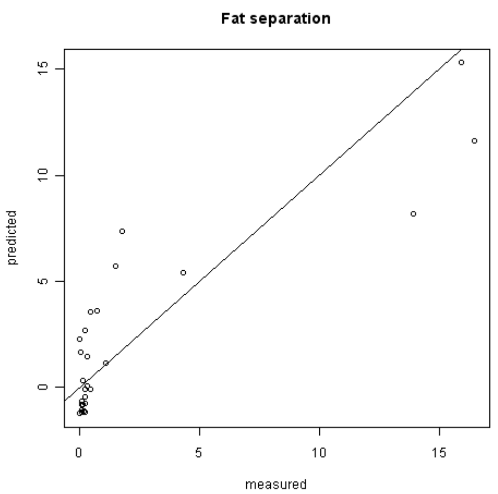

Diagram 3 Fat separation - predicted vs. measured

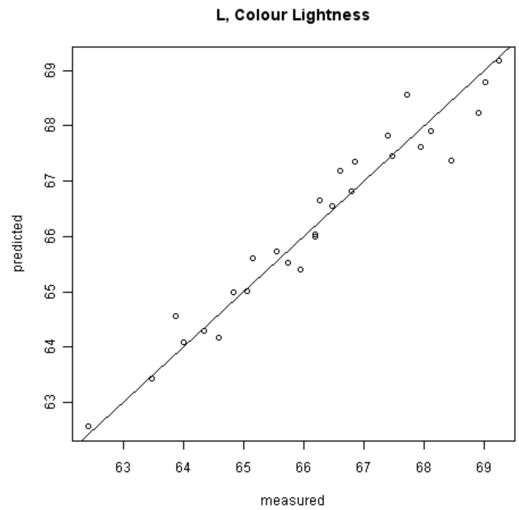

Diagram 4, L (Lightness) - predicted vs. measured

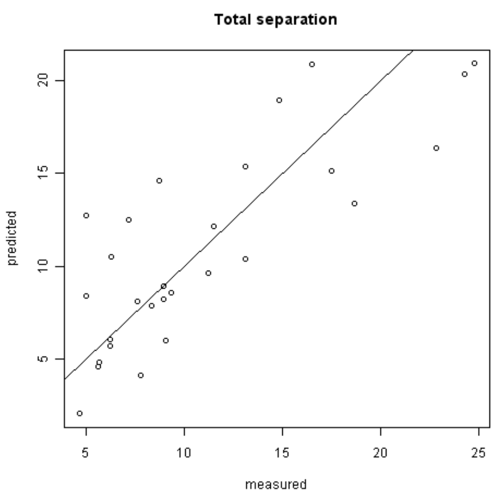

Diagram 5 Total separation - predicted vs. measured

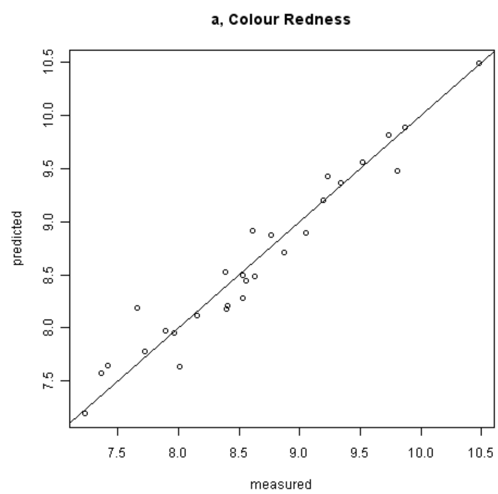

Diagram 6, a (Redness) - predicted vs. measured