PS4.06 **A Method to Evaluate High Accuracy Measurements of Quality Characteristics On-line** 340.00

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***Abstract* - Much equipment has been developed to improve the slaughterhouses' knowledge on the meat being processed, but the equipment is often characterized by having a considerable measuring noise. The aim of this study was to evaluate the consequences of implementing new equipment that measures quality characteristics using mathematical programming and optimization models.**

The experiment was based on data from almost 44,000 pigs being slaughtered at one of the Danish slaughterhouses. A mathematical model of the overall raw material use at the slaughterhouse was developed. After slaughtering different quality characteristics of the carcasses were measured and the carcasses were placed in sorting groups based on these measurements. The sorting groups were used to place the carcasses on bars in the equalization room. In principle, all carcasses placed on one bar would be used for the same products. The purpose of sorting is to reduce variation in the quality characteristics within each sorting group, enabling the slaughterhouses to use raw materials according to their specific quality, e.g. lean meat percentage, pH, colour etc. The objective function of the model is to maximize the value of the carcasses placed on each bar by finding the optimal use of the carcasses. The information required for such computations has been identified, and the effect of improved measuring accuracy was found at six different levels of measuring accuracy. The actual measuring accuracy of the equipment is very important.

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***Index Terms* - measuring accuracy, new equipment, optimization, raw material use, value of knowledge.**

I. INTRODUCTION

The competition within the pork industry is fierce and in these years the industry has an increased focus on cost reductions and effective production. As raw materials are the major cost contributor, the raw material use (raw materials with the right quality for the right products) is very important. The slaughterhouses sort their carcasses into different sorting groups which are well suited for special types of products. Knowledge of the quality is obtained through measurements of for example lean meat percentage, pH, colour, weight of carcasses or products or physical dimensions etc. Much equipment for such measurements has been made but is often characterized by having considerable measuring noise caused by the indirect nature in which the measurements are performed, the hard physical environment in which the equipment is working as well as the large throughput where the required measurements often have to be performed within a few seconds.

How much is knowledge worth?

A procedure for establishing how much such knowledge will be worth is based on mathematical programming and optimization models and depends on the level of measuring accuracy of the new equipment.

II. MATERIALS AND METHODS

The overall principle is to formulate a mathematical model of the raw material use at the slaughterhouses and then solve the model by using optimization software, such as GAMS [3] to find the optimal solution using the current knowledge of the products (with the current measuring accuracy). The model is solved once again, but this time using the improved knowledge of the meat as obtained by the new measuring system. The value of the new knowledge can then be found as the difference in profits between these two optimal solutions.

In the experiment, slaughtering data from almost 44,000 carcasses were used and the model requires the following information:

- Representative slaughtering data including slaughtering weight and lean meat percentage (LMP) or alternative quality measurements.
- Simulation of measuring noise at current and improved levels for each carcass. The current level of measuring error is well known and has been established through previous experiments. Experiments for the new classification system have been performed and the new measuring error

estimated. Already before the equipment was developed, analysis of the consequences at different scenarios of measuring accuracy could be performed.

- Mapping of product alternatives. Each product alternative consists of a "basket" of products. When it is decided to produce one product, the entire "basket" of products will be produced in derived quantities as well. All important product alternatives should be included.
- Prices per kg for the different products.
- Product yields for the different products. Product yields are based on the slaughterhouses' own data or can be found through experiments. Product yields, slaughtering weight and simulated LMP is used to compute the potential value of each product for each carcass.
- Quality requirements. Quality requirements can be measured or simulated depending on the actual knowledge of the raw materials.

Product alternatives

The model has its basis in product alternatives, which can be seen as a "basket" of products, as mentioned previously. In the simple version of the model used here only one product alternative is used of the fore-end, two of the middle piece and two of the ham, a total of 17 different products. See Figure 1 below:

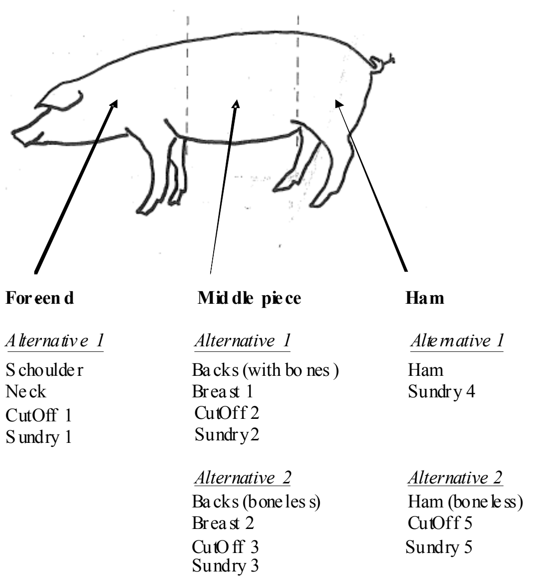

Figure 1. Product alternatives for the fore-end, middle piece and ham.

We have a set of carcasses *I*={1,…,I}. Each carcass can be used to produce different product alternatives *N*={1,…,N} and each product alternative consists of a number of different products *J*={1,…,J}. Finally the carcasses are hung on bars *K*={1,..,K} in the equalization room. The decision variable $y_{k,n}$ is a binary variable with the value 1 if the pigs placed on bar k are used to produce product alternative n and otherwise 0. $U_{j,n}$ controls whether a product is part of a product alternative or not and has the value 1 if it the product "belongs" to the product alternative, otherwise 0. The problem is to find the utilization (product alternative) for the carcasses placed at each bar which optimizes the total profit:

Objective function:

$$1)\ \text{Maximize } Z = \sum_{k,n} \text{ValueBar}_{k,n} * y_{k,n}$$

Subject to the following constraints:

$$2)\ \sum_{n} y_{k,n} = 1 \qquad \forall k$$

$$3)\ y_{k,n} = \begin{cases} 1 \text{ if product alternative n is produced} \\ \text{by pigs placed on bar k, otherwise } 0 \end{cases}$$

Parameters:

$$4)\ \text{ValuePig}_{i,n} = \sum_{j} \left(\text{Price}_j + \text{PriceCoeff}_j * \text{measured quality}\right) * \text{ProdWeight}_{i,j} * U_{j,n}$$

$$5)\ \text{ValueBar}_{k,n} = \sum_{k} \text{ValuePig}_{i,n}$$

Indices:

i : pig i k : bar k j : product j n : alternative n

III. RESULTS AND DISCUSSION

The consequences of improved measurements for the approx. 44,000 carcasses were computed at 6 scenarios with different measuring accuracies and can be seen in Figure 2 below. 0% shows the current measuring accuracy and 100% shows no measuring error at all.

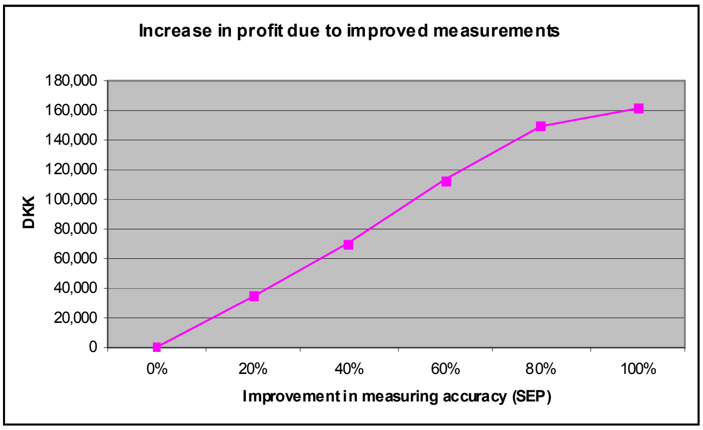

Figure 2. Increase in profit due to improved measurements.

It can be seen that there is a clear improvement in profits and that an improvement of for example 20% is worth DKK 0.77 per carcass when the slaughterhouses have implemented the changed logistics etc.

The model can be improved by including all important products, actual prices as well as sales restrictions from the slaughterhouses. Furthermore, sorting possibilities during processing can be included.

IV. CONCLUSION

- Mathematical programming and optimization models can be used to compute the economic consequences of improved measurements/knowledge of the meat being processed.
- The information required for such computations has been identified.
- Even in the relatively simple version of the model (with only one alternative use of the fore-end, two of the middle piece and two of the ham) an improvement in the measuring accuracy of 20% results in an improvement in profits of DKK 0.77 per pig.
- Measuring new quality characteristics is not enough; the measurements should be precise as well in order to obtain the full potential.

REFERENCES

[1] Kjaersgaard, N. C. (2008), Optimization of the Raw Material Use at Danish Slaughterhouses. Ph.D. thesis, Department of Management Engineering, Technical University of Denmark.

[2] Olsen, E. V. et. al. (2007), On-line measurements in pig carcass classification: Repeatability and variation caused by the operator and the copy of instrument. Meat Science, 75 (2007), 29-38.

[3] GAMS (General Algebraic Modelling System). High-level modelling system for mathematical programming and optimization. www.gams.com.