Using the dynamical stiffness (K_{dyn}) in an egg quality monitoring scheme

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Introduction

The quality of consumption eggs is a result of the interaction between many factors that influence the functioning of the laying hen as an egg producing domestic animal. Egg quality is defined by egg weight, shell strength and internal and external quality. This final quality has to meet up with customer's demands (Frost et al. 1997) and enables the producer to make a profit. As a result the production process is focused on a produce that answers these demands. Therefore it is of great importance to detect a quality decrease as soon as possible, track the cause and take measures. However, in practice there is often a large time span between the origination and the detection of quality loss resulting in economical damage.

Monitoring a production process requires regular monitoring of all the different parameters on both the input side and the output side. Considering the egg production process, a certain line of laying hens are housed in a particular housing system, fed an optimal feed and water and kept in good health (input) so they can produce a maximal amount of good quality eggs (output). During time techniques and devices have been developed to define many of the production parameters (e.g. ambient temperature, relative humidity, feed consumption, water consumption…) on a regular basis and record them automatically on computers (Belyavin, 1988; Frost et al., 1997). On the other hand however, measurement techniques for the egg quality parameters remained slow, often inaccurate, subject to human subjectivity and usually destructive. Recently, fast and non-destructive measurement techniques were developed. Coucke (1998) developed the Acoustic Resonance Technique to assess egg shell integrity and egg shell strength, defined by the dynamical stiffness, K_{dyn}. Already, several researchers presented possible practical applications for K_{dyn}. Lin et al. (2004) used K_{dyn} to investigate the mechanical properties of the eggshell from eggs originating from hens under heat stress. In their research a clear decrease in shell strength as a result of the heat stress was observed which was reflected in both the traditional defined strength parameters as in K_{dyn}. Bain et al. (2006) and Mertens et al. (2006) did research on the predictive capacity of the initial K_{dyn} (measured directly after lay of the egg) in relation to the incidence of an egg breaking in the logistic chain. They both developed a model with K_{dyn} which could give a significant prediction for breakage for eggs originating from hens in different housing systems. Dunn et al. (2005) found that the K_{dyn} showed higher heritability than the traditional egg shell strength parameters indicating its possible use in breeding programs. Finally, Messens et al. (2007) found a significant negative correlation between egg shell strength defined by K_{dyn} and the amount of bacterial penetration by Salmonella Enteritidis.

The presented paper investigated the practical relevance of K_{dyn} as a measure for shell quality in an egg quality monitoring scheme.

Material & Methods

For this experiment, two small experimental flocks of Isa Brown ® laying hens were monitored. The following production parameters were followed in different frequencies: egg production - daily, feed consumption – twice weekly, water consumption - daily, climate - daily, hen weight - weekly and egg quality (egg weight, K_{dyn} static stiffness K_{stat}) - daily. At certain times in the laying period (mid lay 37 weeks and towards end of lay 54 weeks), the hens were challenged with a heat stress in order to generate process changes. The first flock was challenged with a constant heat stress of 32°C during 8 days, while the second flock was subjected to cyclic heat stress (reflecting day-night variations) with a maximum temperature of 35°C in the afternoon.

For monitoring of the mentioned production parameters, a monitoring scheme was developed using quality control charts. Quality control charts are a technique used to perform statistical process control. The basic principle of SPC is to formulate quality limits based on the natural process variability or the common cause variation. Occasionally other kinds of variability, not proper to the considered process, may occur. In this case of special cause variation the quality of the products will fall outside the formulated limits. A quality control chart often used for biologicial processes is the cumulative sum (cusum) chart. The cusum technique directly incorporates all the information in the sequence of sample values by calculating the cumulative sums of the derivations of the mean sample values from a desired target value. This makes the chart sensitive to small process shifts (≤ 1.5σ). (Montgomery, 2005; Devor et al., 1992)

In the developed monitoring scheme, the different data were corrected for time-dependent charachteristics (e.g. increasing egg weight with increasing hen age). This biological trend was subtracted from the data series using models describing the trend of the considered parameter. Mertens et al. (2007) provides a more elaborate explanation on this matter. The resulting residual values after this trend subtraction were then inserted into a cusum control chart to detect deviating values caused by process shifts as a result of the heat stress challenges. Furthermore, these time dependent residual data series were analyzed for Pearson correlation between the different parameters.

Results & Discussion

Figure 1 shows the resulting control chart for K_{dyn} in function of the age of the hens. From this it can be clearly seen that the dynamical strength of the eggs is decreasing when heat stressed is applied to the chickens. The effect of the constant heat stress of 32°C in group 1 had a larger impact on the strength than the cyclic heat stress. This decreased strength was also reflected in the measurements of the static stiffness. Similarly to the decrease in eggshell strength, the egg weight was highly influenced by heat stress resulting in a lower egg weight. Concerning the production parameters on the input side, feed intake was decreased during heat stress, water intake was increased, and hen weight slightly decreased.

In general, K_{dyn} showed a significant fair correlation with feed consumption ($R^2 = 0.73$), water consumption ($R^2 = -0.64$) and average temperature ($R^2 = -0.71$), indicating a change in these parameters to be relatively well reflected in K_{dyn}.

The results of this study suggest the usability of K_{dyn} in a quality monitoring scheme. Unfortunately, in this study, not for all input parameters (hen weight & feed intake) daily data were available. For this reason no suitable model could be developed. Having data of all parameters on a daily basis on one's disposal, it becomes possible to make a model for the prediction of the eggshell strength (K_{dyn}) based on the measurements of the production input parameters (temperature, feed intake, water intake, hen weight).

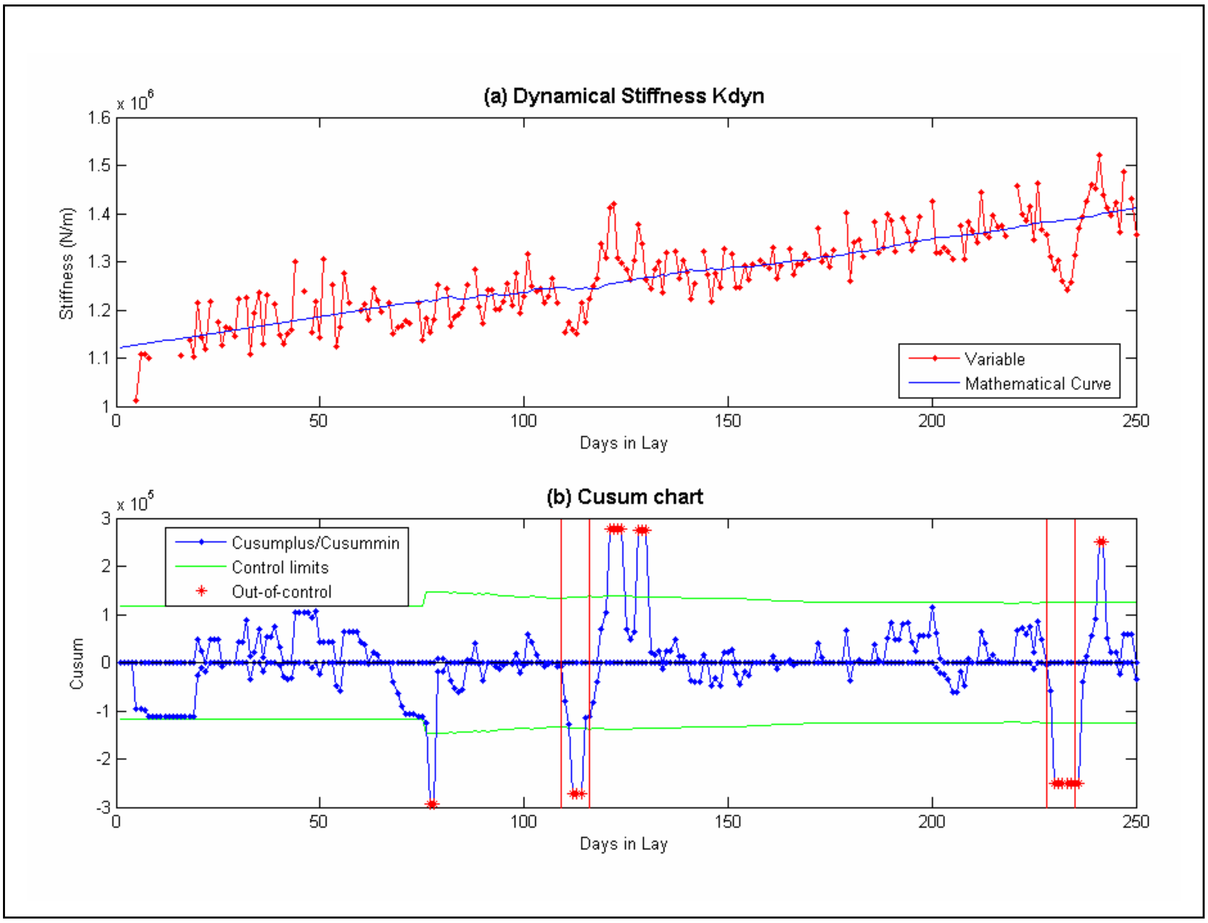

Figure 1: Control chart of the average dynamical stiffness (K_{dyn}) in function of the eggs produced by the hens in group 1 which was subjected to a constant heat stress of 32°C (the vertical lines indicate the application of heat stress). In the upper graph (a) the course of the average Kdyn in function of the age of the hens and the mathematical curve (linear model) is shown. In the lower graph (b) the course of the cusum of the residual values between measured data and mathematical curve is presented.

An important issue in developing such a model is correcting the data for the natural trend in function of hen age. In this study, this matter was addressed by means of fitting a mathematical model based on the measured data which were evaluated to be in-control by the control chart (figure 1). Next, the values from the models were subtracted from the measured values. The residual values then have a normal distribution around a mean value of 0, showing no correlation with the hen's age.
The practical use of using K_{dyn} as a standard measure for shell quality was proven by several researchers. It's predictive capacity for breakage in practice (Bain et al., 2006; Mertens et al., 2006) supplies the opportunity to make an early distinction between strong and weaker eggs. Since weaker eggs will probably not survive impacts occurring in the logistic chain, it would be of interest to sort them out in an early stage of the chain and direct them towards the egg products industry. Furthermore, Messens et al. (2007) have shown that Salmonella E. can penetrate weaker eggs more easily. The combination of these two findings suggests that an early distinction can decrease the risk on broken and/or contaminated eggs. Monitoring K_{dyn} on a daily basis enables the farmer to produce more first quality eggs with an acceptable strength. And when K_{dyn} is even entered in breeding schemes (Dunn et al., 2005), the basic strength of eggs will be enhanced.
In conclusion, in this study showed that K_{dyn} is a useful indicator for shell quality in a quality control scheme for the production of consumption eggs.

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