MONITORING SHELF-LIFE OF MEAT AND MEAT PRODUCTS BY TTI'S

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SUMMARY

Time-Temperature Indicating (TTI) devices with full history temperature response are recognized as a useful tool to monitor or control distribution and as a meaningful alternative to 'sell by' dating for perishable products. The performance of three models LifeLines Fresh-Check labels (type A9, A20 and B43) with reference run-out times of 9, 20 and 43 days at 4,4°C and one prototype model 3M PrimePack Indicator (42 days/6°C) were tested on response kinetics and accuracy at exposure to five temperatures (range −5 to +20°C). Response could adequately described by first-order kinetics and Arrhenius temperature dependancy. However the experimental activation energy and the run-out times deviated slightly from the values declared by the suppliers. This deviations let to deviations between real and expected end of shelf-life indication at the more extreme temperatures. The importance of accurate and reproducible response characteristics is emphasized. Possible applications in the meat industry are illustrated. An example showing the coverage of a shelf-life vs. temperature line for a meat product and a 'matched' TTI label is given.

INTRODUCTION

For the food industry control of temperature is of outstanding importance to guaranty quality, shelf-life and microbiological safety of their produces. Storage or handling conditions for perishable food products are frequently less than ideal in the distribution system. Maintenance of sufficient low temperatures are vital to the quality and safety of such products. The need for a tightly monitored temperature exposure as well as for an alternative for 'sell-by-date' labelling is emphasized because a 'sell-by-date' tells nothing about actual temperature history or temperature abuse. Time-Temperature Indicators with Full-History behaviour (FH-TTI) are nowadays available and can be an useful tool to the food industry to effectuate a close control for temperature critical products during lifetime. A FH-TTI is not a precise temperature recorder but it is a monitor of temperature history that exhibits an irreversible change (mostly in colour) in response to the cumulative effect of time and temperature. At higher temperatures the (colour) change is enhanced while lowering down temperature slows down the rate of change. If the kinetics of reaction controlling the colour state of a PH-TTI tag shows a temperature dependancy which is close to the reactions or changes in a product causing quality loss or decay, it can be used as a visual indicator for quality, freshness or passed shelf-life. To specify a suitable FH-TTI tag for a certain product two things are required. First the relevant and sufficient data for product behaviour as function of temperature within the appropriate temperature range must be known and second the kinetic behaviour of the PH-TTI tag to apply must 'matched' and an appropriate run-out time must be specified.

THEORETICAL CONSIDERATIONS - KINETICS APPROACH TO MODELLING OF FOOD AND TTI RESPONSES

Loss of shelf-life, freshness or stability of many foods can often be evaluated by measurement of one or more characteristic quality parameters. These parameters can be physical, chemical, microbiological or sensorial of nature. Many of this type of reactions can be described by first order or pseudo first order kinetics, especially if a limited temperature range is to be considered (*Labuza 1984; Wells and Singh 1992; Bin Fu and Labuza 1995*). The same mathematical structure of chemical kinetics can be used to describe the response of FH-TTI's (*Wells and Singh 1988*). A first order reaction assuming a rate constant k at a given constant temperature can be expressed by $\ln R' = \ln \frac{\Delta R}{\Delta R_0} = -k.t$, where R' is the dimensionless made reactant concentration or the response 'value' of a TTI at time t. For the temperature sensitivity of the rate constant k the Arrhenius equation can be used. This equation has the form: $k = A.e^{\frac{-E}{RT}}$, where k is the rate constant at temperature T, E the activation energy (J/mol), A the Arrhenius factor, R the molar gas constant (8.314 J/mol.K) and T the absolute temperature in Kelvin.

EXPERIMENTAL DESIGN

In the experiments carried out the responses of four types of TTI with 'full-history' behaviour at different temperatures were validated and checked with compliance this mathematical model. The performance of three models LifeLines Fresh-Check labels (type A9, A20 and B43) with supplier specified reference run-out times of 9, 20 and 43 days at 4,4°C and one experimental prototype model 3M PrimePack Indicator (42 days/6°C) were tested on response kinetics and accuracy at exposure to five constant temperature levels (-5, 0 +5, 10, 15 and 20°C). The given/declared activation energy of all four tested TTI tags were about 92 kJ/mol. Multiple samples of five labels each were packed in a sealed plastic bag and these samples were distributed over five accurately controlled cryo-thermostatic fluid baths. At 10 or more intervals, divided over the expected run-out time of the TTI involved, the colour response was measured in fivefold. For this purpose the optical density (*OD*) of the light reflected from the active zone, reference ring and background of the tags were measured using a optical densitometer (X-Rite model 404GSX, X-Rite Inc, Michigan, USA). The primary measured *OD*-values were transformed to reflection values *R*. After expressing them in dimensionless reflection value *R'*s the logarithmic values were plotted versus temperature exposure times. The found slopes are the *k* values. The experimental found activation energies were estimated by plotting the *k*-values against 1/T. For fitting experimental values to the model equations a sequentially least square linear regression method was applied (*Haralampu e.a 1985*).

RESULTS AN DISCUSSION

TTI response kinetics

Figure 1 gives an example of the plots got when measured TTI response light reflections were plotted against temperature exposure times (LifeLines A9) and in figure 2 the Arrhenius plots for the three tested LifeLines tags are illustrated. The responses of the LifeLines and 3M indicators can adequately described by first order kinetics with Arrhenius temperature sensitivity in the explored temperature range. Reaction kinetics of any other order were less accurate. However it was found that the activation energies *E* for the individual TTI types were different from what was specified by the suppliers (3 to 14 % higher than the given/declared value of 92 kJ/mol) The experimental found *E*-values (in kJ/mol) were 95.2 for A9, 100.9 for A20, 103.8 for B43 and 105.2 for the experimental 3M indicator. This means that the temperature sensitivity of the TTI in the test were higher than expected. This will mean that the run-out times at temperatures higher than the given reference run-out time will be shorter and at lower temperatures longer as declared by the supplier. Also shifts in the specified target run-out times did occur. Both factors results in deviations in run-out times of the indicators in the border ranges of the tested temperature range. The deviations of the experimental versus the declared run-out times for the LifeLines labels are shown in figure 3. Deviations in activation energy *E* results in a slope which differs from the zero line and deviations in reference run-out times results in a shift of the line. The deviation line for the 3M indicator (not given) shows up to +40% longer run-out times at 0°C to -5% shorter times at +20°C in comparison to the declared times.

Example of microbiological shelf-life of pig meat (foil packed) and run-out value of a matched TTI
A real shelf-life line for a given foil packed pig meat product was estimated in the temperature range +1 to +15°C. End of lifetime was defined by reaching a microbiological count of 10^{-7} CFU/cm². From the constructed microbiological shelf- life line (not strictly obeying a Arrhenius behaviour) the *E* value and a reference run-out time for an optimal 'matching' PH-TTI device was derived (*E*-value 92 kJ/mol and run-out time of 2.3 days at 7°C). The fit of the product's and an optimal engineered TTI-tag lifetime curves can be seen in figure 4.

CONCLUSION

A successful and reliable application of TTI's for use as consumer tags requires delivery of TTI- tags by a supplier with can be made tailor made with respect to a reference run-out time and preferably also in activation energy. A controllable and reproducible way of production with respect to kinetics and response characteristics (well defined activation energies and run-out times) should be guaranteed. The importance of accurate and reproducible response characteristics is emphasized in study done.
After careful matching TTI-tag response to the product quality loss or shelf-life stability behaviour, they are a useful tool for monitoring or assurance of the product freshness state at the end of the distribution chain.

ACKNOWLEDGEMENT
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Fig. 1 Reflection response of LifeLines A9 indicator

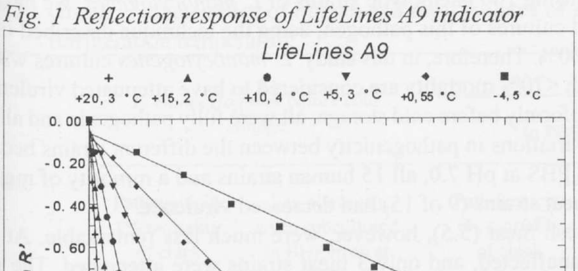

Fig. 2 Arrhenius plots

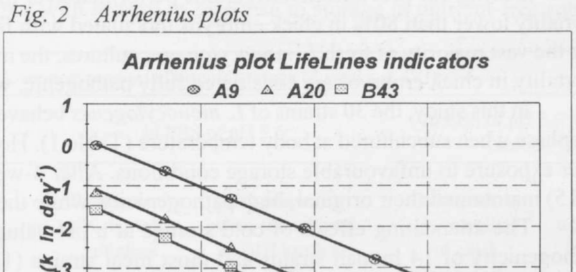

Fig. 3 Deviation experimental run-out time vs. declared times

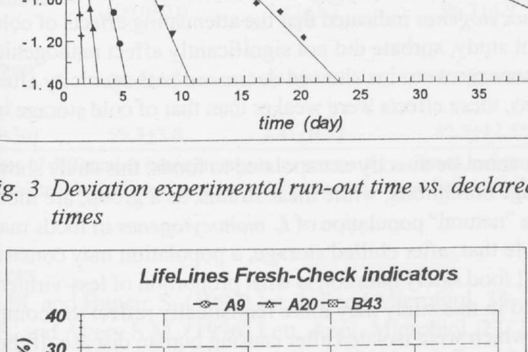

Fig. 4 Shelf-life pig meat foiled packed and run-out time 'matched' TTI-indicator