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Probabilistic shelf life assessment of white button mushrooms through sensorial properties analysis

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ABSTRACT

Sensory test was carried out on different batches of white button mushrooms stored at various temperatures (5, 10, 15 °C and 3.5 °C control) for 5–7days to find the effect of temperature and storage time on the sensory characteristics. Acceptance or rejection of the mushrooms was used to evaluate the shelf life of the product. Sensory data was modelled using mixed-effects logistic regression model. Quality parameters were significantly ($p < 0.001$) affected by the temperature of storage. It was found out that variances for all sensory qualities except cap hardness were more influenced by the panel variation compared to variation between mushrooms in random effect calculation. It was concluded that overall acceptability was more influenced by the cap hardness and maturity of the mushrooms than overall visual quality. A methodology to define conservative estimations of shelf life based on probabilistic assumptions, without resorting to "rule-of-thumb" conservative assessments is presented in this article.

1. Introduction

Fresh mushrooms are judged by their appearance which is well documented by various sensory tests. Consumer preference for fresh cut "quality" produce is gaining a rapid momentum globally, with growing health consciousness and rise in purchase power. In recent years demand for the fresh mushrooms has increased and so is the need for quality maintenance (Brennan, Le Port, & Gormley, 2000). Mushroom quality is usually defined by the whiteness of the cap, blemish less surface, uniformed closed–cup, free of mould or fungus growth; mushroom cap colour being the foremost property that the consumer seek while purchasing (Vízhányó & Felföldi, 2000). Mushrooms are highly perishable products; having higher metabolic rate they degenerate at very faster rate compared to their semi-perishable counterparts. Biological changes in mushrooms are particularly fast as the product tends to loose moisture rapidly and gets discoloured due to enzymatic and/or microbial activities which are triggered by injury or the storage conditions. Consumer acceptability is strongly influenced by the colour, texture and appearance rather than the taste, as buyers often choose the blemish less mushrooms compared to the older mushrooms in spite of the fact that older mushrooms taste better (Eastwood & Burton, 2002).

Sensory evaluation is often biased by individual consumer's perception of "quality" products (Piccolo & D'Elia, 2008). Since sensory analysis is done by a panel of judges, who act like human instrument to measure the quality of a product, it is necessary to check the reliability of repetitive measurement on various occasions (Latreille et al., 2006). Uncertainties are involved due to scoring pattern of the panel and this can add to the variances observed in a sensory study. The variation in individual level is often psychological and to estimate the shelf life using this discrete data can be done by probabilistic assessment of the grouped data.

Heterogeneity of a product assessment is mainly due to biological variance and error variances between sensory evaluator. Biological variation in produce as observed by the consumer, is greatly attributed to the pre-harvest treatment, post harvest processing and storage conditions. Moreover, consumer preference varies in individual level thereby the interpretation of a model product is always a relative term. To interpret and describe the internal phenomena associated with these changes can be well addressed by suitable mathematical models. Most researchers employ descriptive sensory analysis tools (Erickson, Bulgarelli,

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Resurreccion, Vendetti, & Gates, 2007; Piagentini, Mendez, Guemes, & Pirovani, 2005; Sundararajan, Ndife, Basel, & Green, 1999; Villarino, Marsha Dy, & Lizada, 2007) or multivariate data analysis with graphical and tabular results to represent the results (Kreutzmann, Thybo, & Bredie, 2007). In descriptive method, sensory attributes are related to product degradation and shelf life is defined as the time by which the product reaches the acceptable limit. The simplicity of this method presents a skewed picture rather than predicting the actual shelf life (Guerra, Lagazio, Manzocco, Barnabà, & Cappuccio, 2008). On the other hand, multivariate data analysis takes care of number of variables affecting the acceptability, predicts the shelf life in a more meaningful way, but the inconsistent nature of the fresh product, owing to its biological variation itself poses a greater problem in estimation of shelf life in an effective way. A mixed effect model that addresses the internal as well as batch variation, is widely used by various researchers for modelling the quality evolution in fruits and vegetables during post harvest storage (Aguirre, Frias, Barry-Ryan, & Grogan, 2008; De Ketelaere, Stulens, Lammertyn, Cuong, & De Baerdemaeker, 2006; Fonseca, Oliveira, Frias, & Brecth, 2002; Hertog, Lammertyn, De Ketelaere, Scheerlinck, & Nicolaï, 2007; Hertog, Scheerlinck, Lammertyn, & Nicolaï, 2007; Mohapatra, Frias, Oliveira, Bira, & Kerry, 2008; Mohapatra, Bira, Kerry, Frias, & Oliveira, 2010; Montanez et al., 2002; Schouten, Jongbloed, Tijskens, & Kooten, 2004). The evolution of panel and panellists and sensory profiling representing the consumer liking while performing descriptive sensory analysis had also been addressed by mixed effect models (Chabanet & Pineau, 2006; Ortúzar, 2010; Pineau, Chabanet, & Schlich, 2007). Mixed effect models are used to represent the variable data from various probabilistic multidimensional sensory profiling (Caporale & Monteleone, 2004; Latreille, Mauger, Ambroisine, Tenenhaus, Vincent, Navarro et al., 2006; MacKay & O'Mahony, 2002; Smith, Cullis, Brockhoff, & Thompson, 2003), describing both the fixed as well as the random nature of data.

Though various works have been reported on the sensory quality modelling of fruits and vegetables to predict the quality deterioration as a function of temperature and time (Hertog, Lammertyn, et al., 2007; Hertog, Scheerlinck, Lammertyn, & Nicolaï, 2007; Lukasse & Polderdijk, 2003; Piagentini et al., 2005; Smith et al., 2003; Schouten et al., 2004; Vankerschaver, Willocx, Smout, Hendrickx, & Tobback, 1996), shelf life prediction of mushrooms based on sensory analysis estimating both consumer and batch variability is limited. The objective of this research is to develop a mathematical model that describes the time-temperature dependence of each sensory quality attribute of mushrooms taking the batch variability and panel variability into consideration. This model will be used to propagate the estimated variability into the prediction of shelf life in order to allow for the estimation of shelf life times with different confidence levels.

2. Materials and methods

White button mushrooms (*Agaricus bisporus*), sourced from Ranairee mushroom farm, Macroom, Ireland, through a temperature-monitored distribution chain (6 ± 2 °C, and 90 ± 5% RH) were used for this study. Upon arrival, half of the mushrooms were stored in the temperature-controlled incubator at different temperatures (5, 10, 15 ± 0.6 °C) and the corresponding relative humidity was noted (86 ± 7%). The other half of the sample was kept in a domestic refrigerator (3.5 ± 1.5 °C, 92 ± 5%) overnight, as control sample for sensory analysis. A total of 7 batches of sensory study were carried out using a panel of 9 judges.

2.1. Sensory evaluation

A panel of 9 judges evaluated the quality characteristics of all the mushrooms from each day of storage. Each day the samples were removed from the chamber and kept at room temperature for at least 1 h, to bring up the temperature of the mushroom before conducting the sensory trials. The panellists were briefed about the quality of the mushrooms. The sensory evaluation was performed by the panellist in the laboratory under a white back ground, in individual booths. The samples were coded with 3 digit random number. The trained panellists were asked to evaluate the mushrooms based on their overall appearance, texture of cap and stem, gill colour and opening, stipe elongation, flavour and overall acceptability, giving their choice of acceptance or rejection. They agreed that the wilting, bacterial blotch, browning of skin, mould growth, dryness of skin or sliminess of skin would come under overall visual quality (OVQ) and maturity be defined by the stem elongation and cap opening. A scale of 0–10 was used, where 0 stood for extreme dislike and 10 for excellent quality. The score of 5 was considered as limit of marketability and on its basis quality acceptance or rejection was set.

3. Mathematical modelling of the shelf life of mushroom

A generalised linear mixed effect logistic model was fitted to the sensory data (Bates & DebRoy, 2004). Initial model was developed considering the temperature and time dependence on the sensory qualities, which represented the fixed effect term. In the second phase of model development, random terms representing the variability in panel scoring pattern and batch variation was incorporated. The final linear mixed effect model (Pinheiro & Bates, 2000) is represented as:

$$SQ \sim \beta_j + b_i + \epsilon_{ij} \quad (1)$$

Where, SQ is the logistic transformed sensory panel response, β_j is the fixed effect (storage time and temperature) term for the jth mushroom and b_i is random effect term of the ith batch and ϵ_{ij} is the associated error terms, which were assumed to be normally distributed as $(b_i \sim (0, \sigma_b^2), \epsilon_{ij} \sim \mathrm{N}(0, \sigma^2))$.

3.1. Monte Carlo simulation of shelf life

The sensory acceptance and rejection of mushrooms samples when 95% were still acceptable was done by Monte Carlo simulation. The parameters were estimated residual maximum likelihood (REML). The best linear unbiased parameters (BLUPS) were obtained for the random effects.

3.2. Statistical analysis

The linear (lme4) modelling and Monte Carlo simulation were performed using R 2.5.1 software (Bates & DebRoy, 2004; R Development Core Team, 2007).

4. Results and discussion

The cumulative distribution plot of the dependence of the odds ratio of the overall acceptability with storage time and temperature is shown in Fig. 1(a, b). On increasing both temperature and time levels, increase in the rejection odds can be noticed. A similar behaviour (data not shown) was observed for the rest of the sensory analysis responses.

On the basis of those observations from the cumulative distribution plots a logistic model with storage time and storage