Shelf-Life Prediction of Cheese

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Consumers are increasingly concerned about the safety and quality of the food they consume, and they prioritize products that meet strict safety guidelines. Shelf life and food safety are two interlinked concepts, where proper shelf-life assessment is required to ensure food safety. According to Institute of Food Science and Technology (1993), the shelf-life of a food product is described as the period it will remain safe, retain intended sensory, chemical, physical, and microbiological properties, and conform with any label declaration of nutritional data when it is stored under the specified conditions. Thus, the shelf-life of a food is the period upto which the primary characteristics of a food remains acceptable to the consumers in view of its safety and organoleptic quality.

Shelf-life prediction in the food industry holds immense significance as it enables manufacturers to make decisions about product formulation, packaging, storage, and distribution. By accurately estimating the duration for which a food product can retain its quality and safety, businesses can minimize waste, optimize inventory management, and enhance consumer satisfaction. Predicting shelf life allows manufacturers to establish appropriate storage conditions, determine expiration dates, and implement effective quality control measures. It also aids in complying with regulatory requirements, reducing financial losses due to spoilage, and building consumer trust by ensuring consistent product quality. Ultimately, reliable shelf-life prediction serves as a valuable tool for ensuring food safety, minimizing waste, and maximizing efficiency across the food supply chain.

Cheese is the most diverse dairy product, often comes under fermented milk product. It is a perishable commodity due to the dynamic microbiological and biochemical changes that occur throughout manufacturing, ripening, and marketing (Jafarzadeh *et al*., 2021). Cheese production consist of perfectly coordinated series of sequential and concurrent biochemical events during the manufacturing and ripening phases.

Factors affecting shelf life of Cheese

The storage stability of various cheese varies from low (e.g., Camembert, Cottage cheese) to high (e.g., Parmesan). The shelf life of product is controlled by intrinsic and extrinsic factors. Intrinsic factors that affect the shelf life of cheese are the microbiological profile and indigenous enzymes of cheese milk; the gross composition of curd and cheese, that is, residual lactose, salt, protein and fat content; physiochemical conditions of cheese, that is, pH, water activity (a_w) and redox potential (E_h). Salt, pH, water activity and redox potential prevent the growth of pathogens in cheese and minimize spoilage. Extrinsic factors of shelf life of cheese are related to processes and treatments applied during cheese making and throughout ripening and storage, that is, temperature/time combinations, hygiene, storage and distribution conditions are very important (Moschopoulou *et al*., 2019).

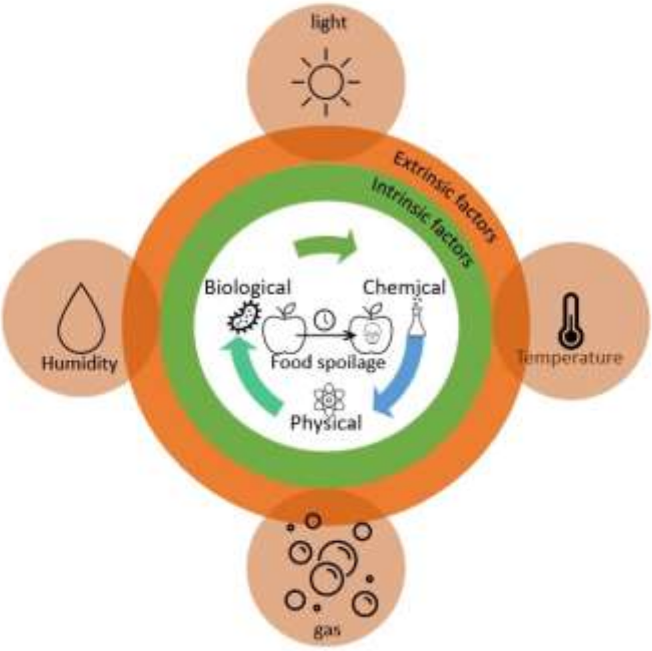

Fig. 1 General factors affecting shelf life of food (**Source**: Choachamnan, 2022)

Shelf-life Assessment of Cheese

Shelf-life assessment considers the specific characteristics of the food product, packaging, and anticipated storage conditions to ensure accurate and reliable shelf-life predictions. It involves three steps: preliminary step, testing and modelling (Nicoli, 2012). Deterioration of food can be due to physical, chemical or biological reactions. In the preliminary step, the factor which has most impact on the quality of food is identified along with the critical indicator which shows the deteriorative event. The acceptability limit of the critical indicator is also described, which distinguish the acceptable product from that having quality changes. The quality indicators can be determined using instrumental analysis (e.g., spectrophotometer, colorimeter etc.), sensory evaluation (Descriptive analysis, consumer acceptance testing, triangle test, hedonic scaling) or by analytical methods (peroxide value, thiobarbituric acid index, GC-MS etc.).

During testing, which can be real time or accelerated, the packed food product is monitored for decay in quality under simulated storage conditions. The shelf life of a food product is a result of complex interaction between intrinsic food features, packaging-related factors, and environmental factors (Calligaris *et al.*, 2019). Practically, testing under actual condition is possible only when it has low storage life i.e., highly perishable food. Shelf-life estimation can be done using real time testing while it is predicted with accelerated testing conditions. In accelerated shelf-life testing, the intrinsic and extrinsic factors are kept constant and the environmental conditions (temperature, %RH, light etc.) are set to accelerate the deterioration of food. Accelerated shelf-life testing is conducted when the quality depletion rate grows as a function of the intensity of the preferred accelerating factor. To that end, the selected quality indicator should be monitored during storage at various degrees of accelerating factor intensity.

Different types of cheese have varying shelf life due to their unique compositions, manufacturing processes, and ageing requirements. Soft and fresh cheeses, such as mozzarella and cottage cheese, have shorter shelf lives, typically ranging from a few days to a few weeks. Semi-hard and hard cheeses, like cheddar and Parmesan, can have significantly longer shelf life, often extending from several months to years. The ageing process and proper storage conditions contribute to the development of desirable flavors and textures in aged cheeses. Shelf-life testing of cheeses is an important aspect of ensuring their quality and safety throughout their expected storage period. Several studies have been conducted to evaluate and predict the shelf life of cheeses using various methods. Park *et al*, (2014) conducted accelerated shelf-life study of cheese and found a shelf life of 0.2 months at 35⁰C. Studies on sliced vacuum-packaged fresh cheese used accelerated shelf-life testing to predict its shelf life. These studies include monitoring of the changes in quality attributes, such as microbial counts and sensory properties, and researchers developed models to estimate the remaining shelf life based on the accelerated testing data. Gürsoy and Altuntas (2020) studied shelf life of Halloumi cheese using sensory and microbial analyses. They evaluated the sensory attributes and microbial quality of the cheese during storage and determined the shelf life based on the changes observed in these parameters. Near infrared spectroscopy is used to predict the shelf life and sensory quality of protected designation of origin (PDO) cheeses. The developed models based on the spectral data to estimate the remaining shelf life of the cheeses and assessed their sensory quality throughout the storage period. Further, to predict the shelf life and to study the changes in quality attributes over time in cheese, statistical models and accelerated testing are sued.

Shelf-life modelling uses mathematical or statistical models to predict the changes in quality of food product over time. These models can estimate the shelf life under different storage conditions without the need for extensive real-time testing. The use of a mathematical model is substantially less expensive, faster in execution, and allows for simulation. That is, multiple shelf-life estimations can be obtained by adjusting one or more model parameters, evaluating the effects of various components, and making predictions about the behaviours in various settings (Piergiovanni and Limbo, 2019). Predictive modelling combines data from different sources to make predictions about product quality and safety over time. Schmidt and Bouma (1992) used Weibull hazard analysis technique to fit shelf-life data (pH, microbial count, sensory characteristics, percent free whey) of cottage cheese to various statistical models. Favati *et al*, (2007) employed predictive modelling to evaluate the shelf life of Provolone cheese packed under protective atmosphere. Kamleh *et al*, (2012) estimated the shelf-life of stored Halloumi cheese using survival analysis with consumer rejection as a failure index. Goyal and Goyal (2012) used Linear Layer (Design) and Multiple Linear Regression models for predicting the shelf-life of processed cheese stored at 7-8°C. Dalzini *et al*, (2017) used predictive models to check the growth of Listeria monocytogenes during storage life Gorgonzola cheese. Diblan and Kaya (2023) reported the shelf-life modelling of kaşar cheese packaged with potassium sorbate, nisin, silver substituted zeolite, or chitosan incorporated active multilayer plastic films.

Conclusion

Accurate prediction of the shelf life of cheese is a vital aspect of ensuring food safety, quality, and consumer satisfaction. Researchers and manufacturers are continuously improving their ability to estimate the optimal storage period for different types of cheese. The development of data-driven approaches further enhances the precision and reliability of shelf-life predictions. Through these advancements, we can minimize waste, optimize inventory management, and guarantee that consumers enjoy cheese at its peak freshness. The on-going efforts to predict the shelf life of cheese contribute to a more sustainable and efficient food industry.

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