

## Impact of Formulation and Packaging conditions on the Shelf-life of Bread

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The concept of shelf-life is fascinating because it combines technological and industrial issues with economic, public policies, and consumer-related ones. The difficulty in clearly defining what shelf-life is has had repercussions on the methodologies developed to carry out its evaluation. This is especially true for the food industry, where companies commonly create their own shelf-life assessment methods with sometimes dubious scientific basis, as they lack a comprehensive and unified perspective on the issue of shelf-life. Many research papers are based on the study of the kinetics of primary shelf-life (PSL), but few of them focus on secondary shelf-life (SSL). This is due to the difficulty of defining the experimental conditions as the package may be opened at different moments through the PSL; furthermore, it causes a sudden change in environmental conditions, determining a strong acceleration in the rate of product quality, making it difficult to predict the final SSL.

This work presents a study applied to the PSL and the SSL of bread in relation to the effect of flour and leavening agents (sourdough and baker's yeast) and modified atmosphere packaging (MAP) conditions (Air and Argon), focusing on determining possible physical-chemical and sensory markers.

According to our results, regardless of the two leavening agents and MAP used, although there were significant differences in some of the chemical parameters of the breads produced, no evident effect of flour on PSL and SSL was observed. Instead, the results showed how the leavening agent used has a major effect on the PSL of breads, especially in combination with the gas used in the package. Compared to Air, Ar combined with sourdough reduces water loss, slows down the staling process, and allows bread to have a longer shelf-life, preserving its initial characteristics. This effect did not occur for bread made with baker's yeast, for which it might be useful to use a different MAP, such as CO<sub>2</sub>.

Indeed, for the SSL, the only effects detected are related to the leavening agents, with a longer shelf-life of sourdough breads compared to the baker's yeast ones. No significant difference could be associated with the use of the two different gases (Ar and Air) in defining the SSL of bread. However, the trend of acceptability (Hedonic Index (HI)) over time can be profitably used as a marker for the evaluation of the SSL of the product. Based on these findings, we can conclude that the decrease in weight and water activity, which are easily and quickly measurable, can be utilized as markers to assess the PSL and SSL of bread, along with sensory analysis.

In conclusion, the work highlighted that the study of the shelf-life of food products is very complex because each product has a different degradation rate correlated to formulation, storage conditions, packaging atmosphere, and also has a specific acceptability limit, defined according to its peculiar qualities. A combined approach, based both on physical-chemical and sensory markers, can be a valid tool to define the primary or secondary shelf-life of foods.

Keywords: Baker's yeast bread; Sourdough bread; Modified atmosphere packaging; Primary Shelf-life; Secondary Shelf-life

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