# Drying behavior of organic apples and carrots by using *k*-means unsupervised learning

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## Objectives

Drying prevents food spoilage and decay through moisture removal due to simultaneous heat and mass transfer from food, which may be stored for long period with minimal deterioration occurring. However, drying technology is not always paired with good/excellent organoleptic, nutritional and/or functional properties of food. In fact, during drying the heat-sensitive substances are often destroyed and degradation processes may be exacerbated due to various and concurrent reaction mechanisms. Based on authors' best knowledge, drying degradation kinetics of biological materials are usually pseudo first-order or first order reactions (i.e. carotenoids degradation in carrots) and may be affected by the initial quality of the product itself. Therefore, the main objective of the proposed study was to investigate the feasibility of *k*-means unsupervised learning to proactively monitor quality change in organic apples and carrots during hot-air drying. Based on authors' best knowledge, fruit and vegetables drying has been widely addressed in literature; nevertheless, little insight is available on smart drying, while knowledge of its potential use in the organic sector is totally lacking.

## Methods

Organic apples (*Malus domestica* B. var. Gala) and carrots (*Daucus carota* var. Romance) were both purchased from a local organic trader and stored at 4±1°C until processing. Apple and carrot samples were both prepared by washing, peeling and cutting them into discs of 5-mm thick. Samples free from decay and/or blemish were used in the experimentation to perform (1) hot-water and microwave blanching pre-treatments and (2) 8-h hot-air drying tests. Apples and carrots were dried at 60 and 40°C, respectively. Batch sampling was performed at 0, 1, 2, 3, 4, 5, 6, 7 and 8 h drying. Each batch was subjected to the analysis of CIELab color, moisture content, water activity, soluble solids content, titratable acidity and pH. Subsequently, *k*-means cluster analysis was performed to determine the number of drying phases on the basis of the observed drying state variables. The best cluster level was chosen as solution at which the actual sum of squared error (SSE) differed the most from the random SSEs. Random SSEs were computed from 300 randomized versions of the original dataset.

## Results

Results were useful to identify drying phases as clusters, performing a *k*-means unsupervised analysis of the drying state variables. The proposed methodology showed very-good (> 90%) selectivity and sensitivity for each drying phase, regardless the pretreatment used. Thus, the method lays the foundations for further researches aimed to the development of accurate and automated drying control systems.