Popular Science Summary

The world population on earth, especially in developing countries, is continuously growing. Therefore, the demand to save food resources while maintaining a high nutritional value increases. To face challenges as malnutrition or food-related environmental issues, technologies with a low energy consumption and thus a low carbon dioxide footprint gain more importance in food processing.

Spinach, one of the globally most produced leafy vegetables, contributes to a balanced diet since it contains several substances which are crucial for essential body functions. It is a good source for minerals such as magnesium as well as several vitamins such as vitamin K or vitamin A. However, leafy vegetables are a food category which decay quickly and therefore, a large amount ends up as food waste. More than 50% of the total food waste is generated by consumers in households. Improving food preservation by prolonging the shelf life of vegetables before packing can be one important way to reduce food waste.

Novel treatments as vacuum impregnation (VI) and pulsed electric field (PEF) or moderate electric field (MEF) are technologies which can possibly lead to shelf life extension. Major advantages of these technologies are that no heat is needed which is useful for heat-sensitive food components and they are low in energy consumption.

VI is a technology which enables the possibility to introduce molecules into the porous structure of a fruit or vegetable. Within this process, the product is placed in a solution containing the desired substances. While vacuum is created, air is removed from the tissue and exchanged with the solution in which the product is immersed. Moreover, with VI it is possible to enrich the diet by introducing substances providing benefits for the human health such as vitamins. In this thesis, vitamin B_1, B_3, B_5 or B_9 solution was introduced into the spinach tissue.

PEF and MEF are electrical treatments. Hereby, electric pulses are applied to the product which results in electroporation. Electroporation means a temporary opening of pores in the cell membranes. So, molecules which are normally retained can leave or enter the cells. Depending on the intensity of the parameters for the electric pulses irreversible or reversible electroporation occurs. The process is termed irreversible if the cells cannot recover and die after the treatment whereas reversible electroporation occurs if the cells can recover and survive. Reversible electroporation was aimed for this study to assure survivability of the cells. So, a suitable protocol leading to reversible electroporation was established. Through the electrical treatment the properties of the plant-tissue are modified which impacts the functionality of the product. By provoking different metabolic processes and reactions as a stress response caused by the electrical treatment it was intended to extend the shelf life.

Hereby, respiration is the most important metabolic process that affects the shelf life of fruits and vegetables.

This study concentrated on assessing the impact on eco-spinach leaves by combining these novel technologies, first VI followed by PEF or MEF, aiming to extend their shelf life. In a first step, the technologies were applied individually to optimise the treatment conditions and then they were combined.

Spinach leaves were treated, packed in bags with holes and stored at 5 °C until spoilage. As retail shelf life, a decay of more than 10% spinach leaves per bag was defined for comparisons of the shelf life among the different the treatments as well as untreated spinach leaves. The atmosphere in the bags was controlled by measuring O_2 and CO_2 concentrations. For the shelf life evaluation, the colour of the spinach leaves was measured and pictures were taken under controlled conditions to record visual changes during the deterioration process.

By exchanging the air with the VI solution the leaves gained weight of 58-65%. This weight gain was mostly caused by filling up air spaces in the spinach tissue with liquid. In the bags containing treated or untreated spinach leaves around 21% O_2 and <2% CO_2 were measured during storage time which corresponds to the composition of the air in the atmosphere. These levels are needed for a high respiration rate. Leaves treated with PEF and MEF did not change their colour whereas VI led to a darker green colour. The different treatments resulted in a faster deterioration of the spinach leaves probably mostly caused by an increased metabolic activity. The combined treatment of VI with vitamin B_3 and PEF or MEF showed the longest retail shelf life with 12 days. The various metabolic processes caused by the different treatments might have had a positive influence upon each other. Thus, cells might be protected better. However, the shelf life was still significant lower compared to untreated leaves with 14 days.

The most striking observation in this work is a significant longer shelf life by combining the different technologies instead of using them individually. The metabolic consequences caused by the different treatments are very complex. Therefore, more investigations are necessary to understand the influence on the metabolism better and thus, improve the shelf life.