Imagine opening a carton-based package of meat after two years of storage on the shelf and finding a small brown discoloration on the surface of the meat – even though the package has never been opened. This could affect the perceived quality of the product. This thesis investigated why this happens and built a practical tool to help analyze this faster.

The short answer is oxygen – but not in the way you might expect.

When we think about food going bad, we usually imagine air getting in. For example, a broken seal, a punctured wrapper, or a lid that was never properly closed. But in this case, the package is sealed perfectly. There is no visible damage, and yet after one or two years on a supermarket shelf, some products develop a brown discoloration. This can be explained as a perceived quality issue – one that can affect how consumers feel about a product they are about to consume.

Here is the surprising part: the length of time the product has been stored barely matters. A product stored in a package stored for 80 months can look almost the same as one stored for 30. That was the result that contradicted one of the main assumptions of this study – that older products would always look worse. Well, this study showed something different. What seems to matter is indeed the well-adhered layers in the multilaminate package and their individual integrity, but also what specific ingredients the products contain and how they were handled before packaging.

So, let's discuss what is actually happening. The food packaging studied is called Tetra Recart®, which is a complex matrix composed of multiple layers of materials, containing paperboard, aluminum foil, and different types of polymers. It is designed to keep food stable for longer periods without the need for refrigeration. During manufacturing, the seals and the folded corners are exposed to higher mechanical stress forces. Over a longer period of storage, oxygen might accumulate and migrate in tiny quantities. Once oxygen reaches the product – even in trace amounts – it might react with the iron naturally present in meat tissue, setting off a slow chain reaction that could gradually create a slight discoloration.

In the majority of discolored cases studied, the discoloration appeared around the vertical seal running up the side of the package and the bottom seal. This consistency is useful because it shows a pattern, and a pattern can be investigated, predicted, and eventually prevented.

The study analyzed ~60 photographs of real discolored cases collected over time, mapping where discoloration appeared and measuring the color shift digitally. As the discoloration could take years to develop, no laboratory experiments were carried out. The results were fully backed up by existing literature and the investigation of a recurring pattern. The main outcome is a practical evaluation method: a step-by-step checklist and decision tree that anyone at the company can use for future cases.

For the food packaging industry – which is under growing pressure to replace plastic with paper-based alternatives – understanding exactly where and why such mechanisms occur is of great importance. This thesis is a small but concrete step in that direction.