The Influence of Different Packaging Materials and Atmospheric Conditions on the Properties of Pork Rinds

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ABSTRACT

Rancidity development in high fat content products is a common off flavor flaw in snack foods. Packaging is often used to avoid spoilage and extend shelf-life. The properties of pork rinds packaged in four different packaging materials with and without nitrogen were studied during 120 days of storage (22 °C, RH 60%, absence of light). The influence of different packaging materials and atmospheric conditions on pork rinds' water activity, hardness, crispness and rancidity development was determined. The PET/PE packaging material had lower barrier properties for the product in both atmospheric conditions compared with PP/metPP (40 and 50 μm) and PET/PETmet/PE. PP/metPP 50 and PET/PETmet/PE with nitrogen atmospheres were demonstrated to be the most suitable packaging materials for pork rinds.

KEYWORDS

Pork rinds, shelf-life, flow packaging materials, rancidity

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INTRODUCTION

Pork rinds are a nutritious snack food made out of pork skin. They are also referred to as scratchings (United Kingdom), scrunchions (Canada), chicharrones (South America) or pork cracklings (New Zealand and Australia) [1] - [4]. The production of pork rinds is a two-step process. First, pork carcasses are typically chilled and de-skinned to produce a gelatinous, tender substance. Stripes of about 1 to 1.5 cm in thickness and 2 to 5 cm in length are cut. Next, skin stripes are dehydrated with pressure and deep-fried under high temperatures (200-220 °C) [5]. The finished product acquires a crisp, puffy feeling in the mouth and, after the addition of salt, a delicate flavor similar to bacon is produced. Pork skin is usually stripped away very precisely, but leaving extra meat on it during carving increases its consumption value. Consumers see pork rinds as a good meat source.

Pork rinds are an excellent source of proteins (approx. 70% w/w) and fats (30% w/w) and contain zero carbohydrates [5]. The fat in the product mainly consists of unsaturated fatty acids that are susceptible to autoxidation. Lipid oxidation is a complex process in which unsaturated fatty acids react with molecular oxygen via a free radical mechanism or in a photo-sensitized oxidation process [6]. Hydroperoxides decompose to an array of volatile compounds, including aldehydes, ketones, esters and acids, which influence food flavor, contributing to rancid, soapy, oily and fishy tastes [7]. It has been shown that lipid oxidation is one of the few reactions that accelerate below the freezing point of water and is related to the water content of fatty tissue [8]. In order to maintain the physical, chemical and sensory quality of the product, proper packaging material must be chosen. This can be achieved by choosing the most suitable packaging material and through the manipulation of the gaseous environment [9]. The general packaging for the rinds is flow packaging and, among others, the following materials are used: PET – polyethylene terephthalate, PETmet - polyethylene terephthalate metallized, PE – polyethylene and PP – polypropylene [10]. Modified atmosphere packaging (MAP) is a popular way to extend product shelf-life [11]. MAP is based on altering the composition of gases in contact with a food by replacing the air in a sealed food package with strictly controlled gaseous mixtures, containing carbon dioxide, nitrogen or other gases [12]. Different packaging materials and techniques are available on the market and therefore the question remains as to which is the best material in terms of cost-effectiveness and the food itself.

The aim of this study was to evaluate the rancidity and texture of pork rinds during a 120-day shelf-life period, packaged under different atmospheres (ambient air and MAP (N₂)) in four different commercial packaging materials.

MATERIALS AND METHODS

Materials

Pork rinds were provided by a local producer. After production the rinds were immediately frozen at -20 °C and stored for 30 days until they were packaged in the studied materials.

Four different packaging materials were provided by a local packaging company. The materials varied in thickness, oxygen transmission rate (OTR) and vapor transmission rate (VTR) parameters; three were metal laminated (PET/PETmet/PE, PP/metPP 50 and PP/metPP 40) and one was transparent (PET/PE) (Table 1). The packaging materials were chosen taking into consideration cost and the parameters for dried foods. The packaging bags were handmade in the laboratory with dimensions of 20 x 26 cm, using a heated sealer ME-500HI (Mercier Corporation Impulse, Netherlands), with a sealing time of 3 seconds and a temperature of...
150 °C. The N$_2$ gas (E941) for packaging was food grade.

**Packaging of the pork rinds**

Frozen pork rind samples were thawed overnight at 22 °C, RH 60%. 40 g of the sample was repacked into four different packaging materials and two different atmospheres: N$_2$ (100%) and atmospheric air with 21% O$_2$. The packages were sealed with a vacuum packer Lynx 32 (Henkelman, Netherlands) and a heated sealer ME-500HI, respectively. The packaged samples were stored in a closed container at 22 °C and an RH of 60% in the absence of light until analysis.

**Head-space analysis**

The oxygen concentration in the packaging was analyzed with an Agilent 490 Micro GC Biogas Analyzer, equipped with a CP-Molsieve 5A channel (pressure 200 KPa, injector temperature 110 °C and column temperature 80 °C; the carrier gas was argon), a CP-PoraPLOT U channel (pressure 150 KPa, injector temperature 110 °C and column temperature 80 °C; the carrier gas was helium), and a thermal conductivity detector. At the time of analysis, the packs were retrieved from storage and measured one by one. An apparatus injection needle was used to penetrate the packaging material. Before injection, the specific piercing area was covered with a special patch material to prevent excess leaking from/into the pack environment. After a two-minute test, the patches were removed and the holes were sealed with strong sealer tape. The samples were analyzed in triplicate at the beginning of the experiment and at the end of a 120-day shelf-life period. To prevent any changes in the pork rinds due to the destructive method, samples were tested for water activity and texture on the same day.

**Water activity**

The water activity ($a_w$) of the pork rinds was determined using an Aqualab water activity analyzer (Meter Group, USA). The samples were pulverized for 30 seconds in a mortar and immediately inserted into the analyzer to prevent water uptake. The analysis was run in triplicate, analyzing a single rind from each pack, one at a time (n=3x2).

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Table 1: Parameters of the packaging materials

<table>
<thead>
<tr>
<th>Packaging material layers</th>
<th>Thickness (μm)</th>
<th>Oxygen transmission rate (OTR) (cm$^2$m$^{-2}$/ 24h 23°C 0% RH)</th>
<th>Vapor transmission rate (VTR) (g m$^{-2}$ 24h 38°C 90% RH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(PET/PETmet/PE)</td>
<td>74</td>
<td>1.7</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Polyethylene Terephthalate/ Polyethylene Terephthalate metallized/ Polyethylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PET/PE)</td>
<td>52</td>
<td>2.4</td>
<td>&lt; 10</td>
</tr>
<tr>
<td>Polyethylene Terephthalate/ Polyethylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PP/metPP)</td>
<td>50</td>
<td>90</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Polypropylene/ metallized Polypropylene</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PP/metPP)</td>
<td>40</td>
<td>100</td>
<td>≤ 1</td>
</tr>
<tr>
<td>Polypropylene/ metallized Polypropylene</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Hardness and crispness**

Hardness and crispness were analyzed with a Texture analyzer TA-XT2i (Stable Micro Systems, UK), using a 3-mm diameter lance probe. The samples were compressed 25% at a speed of 1.0 mm/s. Compatible software for the texture analyzer made it possible to determine the hardness and crispness of the samples at the same time during compression. The graph generated revealed peaks when the probe pierced the samples. Every peak represented the resistance force to the probe by the measured sample. The highest peak was interpreted as the hardness of the product, expressed in Newtons (N). Crispness was interpreted as the total peak count. The analysis was run in triplicate, analyzing a single rind at a time (n=10) from each pack.

**Sensory analysis**

Sensory analysis was conducted with a trained panel of eight assessors using descriptive sensory analysis. The analysis was comprised of a group of test methods (a flavor profile [13] and a texture profile [14]) to quantify the perceived sensory intensities of the product [15].

The analysis was run in triplicate, with a total of five sessions in 120 days for sample evaluation. During these sessions, the sample packs were opened one by one and each assessor had access to the food samples. The samples were described in terms of rancidity and texture attributes using a 0 = none/chewy to 15 = very strong/too hard scale with increment points of 1. Purified filtered water and reference materials (heated rapeseed oil for rancidity, TUC crackers for crunchiness and puffed rice cakes for crispness) were available at all times. The assessors were told to clean their palates in between the samples.

**Statistical analysis**

The results from each analysis were subjected to analysis of variance (ANOVA), and significant differences (p ≤ 0.05) between the samples were found.

**RESULTS AND DISCUSSION**

**Head-space analysis**

Oxygen contents in the head-space were measured to find the changes in the oxygen level by packaging materials. The mean oxygen content in the headspace of packages without pork rinds was 21.53% (Table 2) that is 0.58% more than theoretical value of atmospheric air (20.95%). The oxygen content in the head-space of the pork rinds packed without N₂ after 30 days of storage was less than in empty packages and decreased with 120 days of storage in all packaging materials. It can be assumed that the oxygen was consumed in oxidation reactions as the level of oxygen in the empty packages did not change.

The pork rinds packed with N₂ showed low oxygen content after 30 days of storage in all packaging materials. After 120 days of storage, the oxygen content of the PET/PETmet/PE, PET/PE and PP/metPP 40 packaging materials remained the same, while the oxygen content of PP/metPP 50 increased to 2.55±0.20%. It is clear (Table 1) that the OTR of PP/metPP 50 was high (90 cm³/m²/24h 23°C 0% RH), which explains the small increase in the oxygen content.

**Water activity**

Pork rinds are a heterogeneous product with low water activity (a_w < 0.36) (Table 3). Jensen & Risbo [16] found pork rinds had an even lower a_w value of 0.17. This is probably due to the variations in drying of the product. With this low value, pork rinds are microbiologically stable but chemical and enzymatic reactions can occur which result in deterioration [17]. Products with low water activity are susceptible to rancidity, with the O₂ atmosphere
Table 2: Effect of storage on oxygen content in the head-space of different packaging systems, with and without pork rinds

<table>
<thead>
<tr>
<th>Storage time (days)</th>
<th>Packaging without pork rinds</th>
<th>Packaging with pork rinds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>120</td>
</tr>
<tr>
<td>PET/PETmet/PE without N₂</td>
<td>21.48±0.10%</td>
<td>21.52±0.06%</td>
</tr>
<tr>
<td>PET/PE without N₂</td>
<td>21.64±0.06%</td>
<td>21.45±0.05%</td>
</tr>
<tr>
<td>PP/metPP 50 without N₂</td>
<td>21.61±0.03%</td>
<td>21.57±0.02%</td>
</tr>
<tr>
<td>PP/metPP 40 without N₂</td>
<td>21.67±0.05%</td>
<td>21.51±0.05%</td>
</tr>
<tr>
<td>PET/PETmet/PE with N₂</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>PET/PE with N₂</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>PP/metPP 50 with N₂</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
</tr>
<tr>
<td>PP/metPP 40 with N₂</td>
<td>&lt;2%</td>
<td>&lt;2%</td>
</tr>
</tbody>
</table>

Table 3: Effect of storage time on the water activity of pork rinds packaged in different packaging systems

<table>
<thead>
<tr>
<th>Storage time (days)</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET/PETmet/PE without N₂</td>
<td>0.352±0.002</td>
<td>0.341±0.008</td>
<td>0.327±0.017</td>
<td>0.336±0.006</td>
</tr>
<tr>
<td>PET/PE without N₂</td>
<td>0.337±0.000</td>
<td>0.410±0.000</td>
<td>0.410±0.000</td>
<td>0.462±0.006</td>
</tr>
<tr>
<td>PP/metPP 50 without N₂</td>
<td>0.317±0.001</td>
<td>0.308±0.001</td>
<td>0.307±0.022</td>
<td>0.303±0.002</td>
</tr>
<tr>
<td>PP/metPP 40 without N₂</td>
<td>0.332±0.008</td>
<td>0.301±0.011</td>
<td>0.302±0.003</td>
<td>0.285±0.011</td>
</tr>
<tr>
<td>PET/PETmet/PE with N₂</td>
<td>0.320±0.018</td>
<td>0.318±0.001</td>
<td>0.308±0.000</td>
<td>0.295±0.009</td>
</tr>
<tr>
<td>PET/PE with N₂</td>
<td>0.342±0.008</td>
<td>0.422±0.001</td>
<td>0.429±0.001</td>
<td>0.480±0.002</td>
</tr>
<tr>
<td>PP/metPP 50 with N₂</td>
<td>0.327±0.004</td>
<td>0.309±0.000</td>
<td>0.303±0.005</td>
<td>0.277±0.008</td>
</tr>
<tr>
<td>PP/metPP 40 with N₂</td>
<td>0.335±0.001</td>
<td>0.314±0.071</td>
<td>0.306±0.017</td>
<td>0.302±0.014</td>
</tr>
</tbody>
</table>
in the \(a_w\) range of 0.10 to 0.30. The reaction is the lowest at \(a_w\) 0.32 and increases again in the range of 0.32 to 0.75 [17]. The water activity of the analyzed pork rinds remained in the range where the rancidity reaction was the slowest, supported by the sensory analysis, where the rancidity perception results remained low.

The water activity of the pork rinds packed in PET/PETmet/PE, PP/metPP 50 and PP/metPP 40 with and without \(N_2\) slightly decreased during 120 days of storage, probably due to the slow hydrolytic oxidation process. However, the water activity of pork rinds packed in PET/PE with and without \(N_2\) increased during storage. This was due to water permeation through the packaging material, since PET/PE has higher vapor permeability (< 10 g m\(^{-2}\)/24h 38°C 90% RH) compared with the other studied materials (Table 1).

**Hardness and crispness**

Pork rinds are a very heterogeneous food product and the mean hardness of the product packed in different packaging systems was 44±15 N (Figure 1 a and b). As the starting point of the experiment conformed to the first measurement point of the storage time, the results are not shown graphically. Different packaging systems and the storage time presented no statistically significant differences in hardness between the packagings PET/PETmet/PE, PP/metPP 50 and PP/metPP 40 at the 95% confidence level (p<0.05). However, the hardness of the pork rinds packed in the PET/PE material with or without \(N_2\) increased over 50 N during the storage time. This is clear evidence of “moisture toughening”, which is the loss of brittleness accompanied by a corresponding increase in the apparent hardness. This is probably a manifestation of the progressive inability of fractures to propagate, thus allowing the particles’ beds to resist an increasing amount of compressive stress. This phenomenon has also been observed with pork rinds by Gonzalez Martinez, Corradini and Peleg [18].

Crispness was recorded through the peak count generated by measurement by piercing the sample. The more brittle the sample, the higher the peak count. The pork rinds’ mean peak count was 20±5 (Figure 1 c and d). Again, different packaging systems and the storage time presented no statistically significant differences in crispness between the packagings PET/PETmet/PE, PP/metPP 50 and PP/metPP 40 at the 95% confidence level (p<0.05). However, the crispness of the pork rinds packed in the PET/PE material with or without \(N_2\) decreased during storage, presenting the mean peak value of 24±8 after 30 days of storage and 7±4 after 120 days of storage. This means that the texture of the pork rinds packed in PET/PE changed from crispy to tough/chewy. This change was due to moisture migration through the packaging material.

As texture contributes to the overall enjoyment of the deep-fried snacks [5], the mean peak count value of <10 is seen as non-consumable texture value in relation to the sensory analysis.

**Sensory analysis**

The sensory attribute ratings, i. e. rancid off-flavor, hardness and crispness during the storage time of the pork rinds, are shown in Figure 2. On a 15 point scale, a rancid attribute rate close to 15 and texture attribute rates close to zero indicate growing negative values, i. e. unacceptably rancid was rated as 15, and too hard and crispy was 0. Opposite scales were chosen according to human perception: unacceptable taste was measured as increasing and good texture (crisp) in the mouth as decreasing. As the starting point of the experiment conformed to the first measurement point of the storage time, the results are not shown graphically. Different packaging systems and the storage time presented significant changes in rancidness, with a distinguishable change during storage at the 95% confidence level (p<0.05).
It is well known that oxygen elevates lipid oxidation rate in food [1], [6], [19]. It has also been proven that an N\textsubscript{2} atmosphere prevents rancid flavor development in foods during storage [20] - [22]. Pork rinds packed in different packaging materials without N\textsubscript{2} (Figure 2 a) developed distinguishable rancid off-flavor 60 days after packaging. The rancid off-flavor can be described as a strong, easily identified, negative sensory characteristic defined as unacceptable for consumption. By 120 days, off-flavor intensity was highest in rinds packed in PET/PE and lowest in rinds packed in PET/PETmet/PE and PET/metPP 50. As PET/PE has high VTR and the water activity of the samples increased during storage, there may have been hydrolytic oxidation in addition to auto-oxidation.

N\textsubscript{2} packaging significantly retarded the lipid oxidation, as no rancid off-flavor developed in N\textsubscript{2} packaged samples throughout the storage period, except with PET/PE packaging (Figure 2 b). The rancid off-flavor development in PET/PE packaging with N\textsubscript{2} likely resulted from excessive moisture in the packaging causing hydrolytic oxidation.

**CONCLUSIONS**

The texture changes and rancidity development in the packaged pork rinds during 120 days of storage was studied. These results are of particular interest to food production companies in terms
Figure 2. Descriptive sensory analysis ratings of pork rinds packed in different systems during the storage time.
of selecting the most suitable packaging system to extend the shelf-life of the product. Four commercial packaging materials with different permeability parameters were compared. It was shown that pork rind property changes were associated with the different properties of packaging materials. The sensory rancidity of rinds packed in PET/PE of 52 μm with or without N$_2$ increased to an unacceptable level. Additionally, the texture of the rinds packed in this material both with and without N$_2$ changed substantially and showed negative changes in terms of chewiness. So this material proved to be an unsuitable barrier, having the highest VTR compared to the other studied materials.

Pork rinds packed in PET/PETmet/PE 74 μm, PP/metPP 50 μm and PP/metPP 40 μm without N$_2$ started to develop detectable rancid off-flavor after 90 days.

The packaging systems PET/PETmet/PE 74 μm and PP/metPP (50 μm) with N$_2$ were found to be good systems for preventing rancidity development and textural changes of pork rinds after 120 days of storage.

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