INHIBITION OF WARMED OVER FLAVOR IN PRE-COOKED MEAT

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SUMMARY

Warmed Over Flavor, WOF, the rapid onset of rancidity in cooked meats during chill storage, is strongly dependent on the cooking temperature and the packaging method, whereas the chilling temperature during storage is of little importance. Detection of WOF in pre-cooked beef and pork by determination of thiobarbituric acid reactive substances, by gas chromatographic determination of hexanal as a volative oxidation product, and by determination of fluorescent oxidation products has been compared with evaluation by a trained sensory panel. Each of the analytical methods did show a high correlation with the scores of the sensory evaluation, and can be recommended as objective WOF detection methods. Excessive cooking is critical and a compromise between sensory properties and microbiological safety has to be attained for each type of product. As first step in the process of developing cook-chill systems in which the WOF-phenomenon can be minimized, vacuum-packaging as well as modified atmosphere packaging were tested. Using oxygen barrier material, both of these packaging method did retard the development of WOF.

INTRODUCTION

In 1958, Tims & Watts named the rapid onset of rancidity in cooked meats during storage "Warmed Over Flavor" (WOF). In contrast to the more slowly developing rancidity in raw meats, this off-flavor in cooked meats is detectable after only 12 hours and is strongly accentuated on the reheating of the meat. WOF is recognized by consumers as "left-over" taste or rancid taste, and it is often determining the quality and shelf-life of pre-cooked, ready-to-eat meat products. Thus, the need for further research in solving problems in relation to WOF is well recognized (Gray & Weiss, 1988). We have undertaken a research programme including both basic research on the mechanisms of the development of WOF, and establishment of analytical methods for objective detection of WOF, as well as applied research in order to determine the effects of different processing parameters on WOF in pre-cooked meats. Preliminary results are presented, mainly dealing with the effect of the cooking temperature, the influence of added spices, and the effect of packaging methods (air, vaccum, modified atmosphere) on the development of WOF in pre-cooked beef and pork slices during chill storage.

MATERIALS and METHODS

Two experiment design are in use in our research on the WOF phenomenon:

Method 1:

Meat, lean beef (4-5% total fat) or pork, was cooked (either as a round steak cooked in a conventional oven, chilled, sliced and packed or sliced, vacuumpacked and cooked in a waterbath), and placed in an open chill cabinet (illuminated or dark, 4-5 °C) for 10-14 days. Three different packaging methods has been used: Vacuum (VAC, vacuum level 99%) and Modified Atmosphere Packaging (MAP) in 70%N_2/30%CO_2 , both in a laminate material (low O_2-permeability: 60 $cm^3/m^2 \cdot 24h \cdot bar$), or, as the third method, in sealed polyethylene bags (PE) (high O_2-permeability: 3800 $cm^3/m^2 \cdot 24h \cdot bar$). During the storage period, samples were withdrawn and analyzed periodically by the following methods of analysis. All samples were reheated in a microwave oven to approx. 75°C prior to analysis.

Sensory evaluation. A sensory panel of 6-8 trained panelists was used for the evaluation of the reheated samples. The evaluated

Parameters were: "WOF-smell", "WOF-taste" and "Meat taste". For each parameter, the score was given either on a 10 cm line scale or on a hedonic 0-10 scale with 5 fixpoints with descriptive words, in both cases ranching from "not detectable" to "extreme". The marks given on the line scale by the panelists were simply converted to scores by measuring the distance in mm from the end of the scale (range 0-100 mm). At each test session, an initial adjustment of the panel was done by serving samples with known organoleptic properties, i.e. both freshly cooked samples and samples with a certain development of WOF. The test session itself consisted of evaluation of 6-8 samples, partly samples in duplicate.

Thiobarbituric Acid Reactive Substances (TBARS). The TBARS were determined by the extraction method of Vyncke (Vyncke 1975). All samples were analyzed in duplicate and results were expressed as "equivalent μmole malonaldehyde / kg meat".

Gas chromatography (GC). Volatiles, including secondary lipid oxidation products, were concentrated by a dynamic headspace method. By N_2-purging the volatiles from a reheated beef sample was collected in a Porapak Q-trap, eluated with diethyl ether and injected in the GC (HP 5890A , column Carbowax 20M C. Temperature programming: 70°C for 10 min, 70°-190°C by 3°C/min, 190°C for 20 min.). Samples containing pure compounds (aldehydes, acids, ketones etc.) were analyzed under the same conditions to determine the retention times for likely secondary lipid oxidation products. Admittedly, the retention times are only to be considered as guidelines and this procedure does not provide a satisfying identification of all the oxidation products. However, the main oxidation product hexanal was easily identified by a recognizable peak in the chromatogram. The area of this peak was used to calculate the relative hexanal content which was taken as the area of the peak relatively to the area of the internal standard peak.

Fluorescence spectroscopy. Fluorescent oxidation products were extracted from the meat by a modification of the method of Fletcher et al. (1973) and Kamarei & Karel (1984). The fluorescence measurements were performed on an SLM48000S spectrofluorometer: Extracts were excitated at 360nm, and the intensity of the emission at 440nm was measured relatively to a quinine sulfate standard (1ppm in 0.5M H_2SO_4 equals 100).

Method 2:

In order to test the antioxidative activity of different substances, a model system have been developed, as described in detail in Bertelsen et al. (1991), and used mainly to test the influence of different spices on the lipid oxidation in cooked meat during subsequent chill storage. Cooked beef was covered by a hot water extract of the particular spice and stored at 4°C. Periodically, separate samples were taken and the TBARS and/or hexanal by GC were determined, as described above.

RESULTS and DISCUSSION

Packaging methods. Figure 1 shows the results from the sensory evaluation of the meat during chill storage. The onset of the WOF-taste occurs within the first day of chilling for beef slices packed in PE bags, rising to an almost constant level (from day 3 until day 10). The decline in the WOF from day 10 to day 14 is due to the onset of other off-flavors resulting from bacteriological deterioration. As may also be seen from this figure, the WOF of the vacuumpacked and MA-packed meats remain at the same low level during the chill storage. The development of WOF is clearly an oxidation phenomenon, and the accessibility of oxygen during storage has a major influence on the development of WOF.

Comparison of analytical methods. In order to correlate the result of analytical methods commonly in use for assessment of the degree of oxidative deterioration of food and biological tissue with the sensory perception of WOF, the same product was followed by sensory evaluation and chemical analysis during storage. The results of determination of TBARS, of hexanal, and of fluorescent oxidation products are displayed in figures 2, 3, and 4. To our knowledge, the fluorescence method has not previously been used in the detection of WOF. For all three methods and throughout the chilling period a constant low level of oxidation products is seen for the vacuumpacked and the MA-packed samples in good agreement with the results of the sensory evaluation. Likewise, for the PE-packed samples a rapid increase in oxidation products correlates with the results of the sensory evaluation, as seen for all three methods.

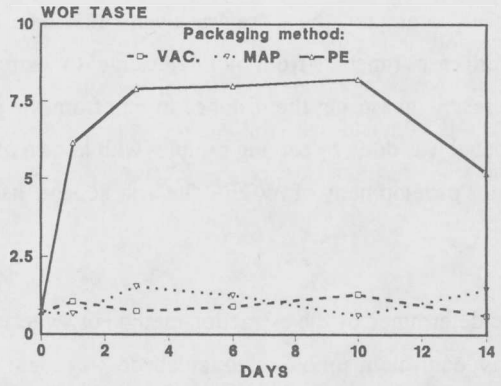

Fig. 1. The development of the score "WOF taste" from the sensory analysis of cooked beef samples during chill storage (4°C, dark). Different packaging methods are compared : Vacuum (VAC), MAP (70%N_2/30%CO_2) and in air-filled polyethylene bags (PE).

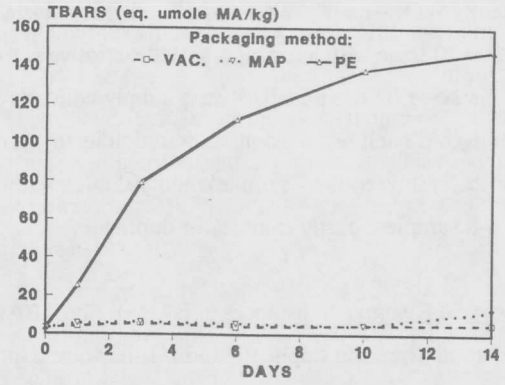

Fig. 2. TBARS development during chill storage, same samples as fig. 1.

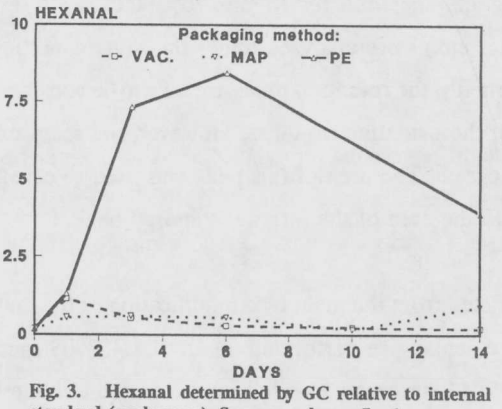

Fig. 3. Hexanal determined by GC relative to internal standard (peak areas). Same samples as fig. 1.

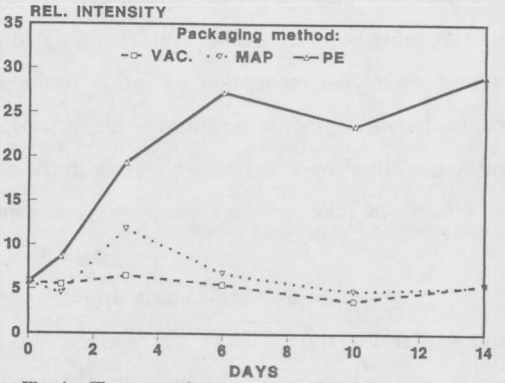

Fig. 4. Fluorescent intensity (excitation 360nm, emission 440nm) relative to quinine sulfate standard (1ppm in 0.5M H_2SO_4 equals 100). Same samples as fig. 1.

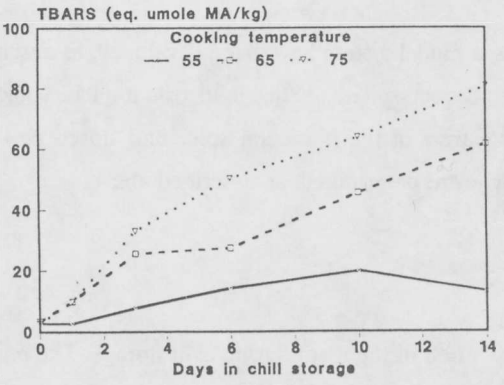

Fig. 5. The development of TBARS during chill storage of sliced beef, cooked at different temperatures before storage.

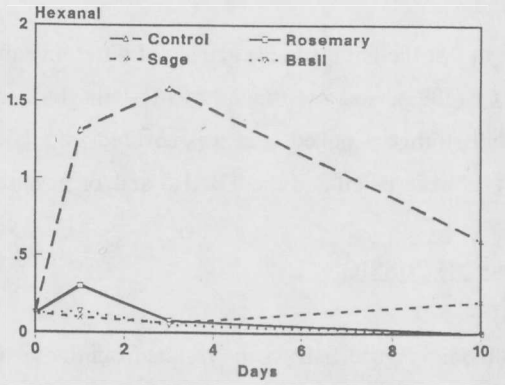

Fig. 6. The effect of certain spices on the lipid oxidation in cooked beef during chill storage, measured by GC as the content of hexanal relative to internal standard (peak areas).

Cooking temperature. Figure 5 shows the influence of the cooking temperature on the development of the TBARS during subsequent chill storage. The beef was sliced, vacuumpacked and cooked for 20 min. in a waterbath at 55°C, 65°C and 75°C. In the temperature range investigated an increase in cooking temperature results in dramatic increase in lipid oxidation. As the result of an increase in cooking temperature from 65°C to 75°C, the onset of secondary oxidation products detected as TBARS appeared approx. 4 days ealier for the higher temperature. Excessive cooking is critical for development of WOF and a compromise between sensory properties and microbiological safety has to be attained for each product. Higher cooking temperatures were also tested (results not shown), and notably, increase from 75°C to 90°C or 100°C did not result in further development of TBARS.

Superchilling. Superchilling (SC) (-2°C) has been compared to conventional chilling (5°C), in order to evaluate the temperature effect during storage of cooked pork. Samples were vacuumpacked or PE-packed, and stored for 20 days. For neither of the packaging

methods no significant difference between the two chilling methods was detected in the sensory analysis. In accordance with this result, no significant difference was found in the amount of TBARS and in the amount of fluorescent oxidation products for the two chilling temperatures. In agreement with the packaging experiment with beef at conventional chilling, a significant difference was found between the two packaging methods for superchilling. Our results clearly show, that a correct packaging method with exclusion of oxygen, is far more important than the chilling temperature in preventing the development of WOF.

Spices as antioxidants. The results of a series of experiments with different spices added as natural antioxidants are displayed in Figure 6. The development of WOF was followed during chill storage, and as may be seen from Figure 6, each of these spices are capable of reducing the lipid oxidation in the actual product. Moreover, these results are in accordance with the analysis of TBARS (not shown). The extraction method used for the analysis of fluorescent products co-extracted fluorescent substances originating from the spices hampering the use of the fluorescence method. Until now 20 spices, of which many have shown similar potentials as antioxidants, have been screened.

CONCLUSION

Excessive cooking is to be avoided in order to prevent WOF, and the cooking temperature has to balance between optimum sensory quality and microbiological safety. The chill storage temperature used after cooking is of less importance compared to the choice of packaging method. The packaging method is the most important factor in avoiding the appearance of WOF in cooked meat during subsequent chill storage. Modified atmosphere and vacuum packaging have each proved to be effective in the exclusion of oxygen below a critical level to retard WOF effectively. Natural antioxidants such as spices might prove to be an effective way of reducing the lipid oxidation in cooked meats, allthough it should be borne in mind, that the choice of spice can affect the sensory quality negatively. The three analytical methods used in our experiments, i.e. determination of TBARS, hexanal and fluorescent oxidation products, all showed a high degree of correlation with the sensory analysis concerning the development of WOF.

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