

Assessing Water Activity in Dry-Cured Ham using Microwave Spectroscopy

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Abstract— Microwave spectroscopy have been applied in numerous applications in the non-food industry, and recently also in the food industry, for non-destructive measurements. In this study, a dry-cured ham model was designed and water activity, water content and salt content (sodium chloride) were determined for all samples using chemical analysis. The water activity was also measured using microwave spectroscopy, with a rectangular microwave cavity resonator. Attained results indicate that microwave spectroscopy might be a promising technique for determination of water activity in dry-cured ham.

Keywords; Dry-cured ham; microwave; water activity.

I. INTRODUCTION

Microwave spectroscopy has become a well-known technique in the non-food industry, including applications for determining particulate blend composition on-line, biomedical measurements, and humidity detection [1-4]. The advantage of this technology is that it can be implemented cheaply, yet be used for a wide range of applications in a robust and non-destructive manner. Recently, microwave spectroscopy has also been applied in the food industry, and previous study shows that microwave spectroscopy is a promising technique for determining the water holding capacity (WHC) of raw meat [5]. Being able to measure different quality parameters during the dry-curing process of ham is also of a great interest.

Water activity is an important parameter for controlling the production and quality of dry-cured meats. Water activity is defined as the current volume and availability of “free” water in a sample, and is given in values ranging between 0 (absolute dryness) and 1 (condensed humidity). Meat products have high moisture content, thus their water activity lies in the upper range of the water activity scale for foods. Fresh meat has water activity above 0.99, while water activity for dried meat products is lower, between 0.92 and 0.80. It is the availability of water for microbial, enzymatic or chemical activity that determines the shelf life of food and with reduced water activity the shelf life and safety of meat products improves [6].

Non-destructive and rapid on-line measurements would simplify and improve the production and quality control. The microwave sensor operates in a wide range of microwave frequencies, providing selectivity in real time detection of

water activity. The main goal with the project is to develop an on-line non-destructive instrument for measuring different quality parameters for raw and dry-cured meat, including water activity. The first step in the project was to investigate whether water activity can be predicted using microwave spectroscopy. In this purpose, a dry-cured ham model was designed and analysed.

II. MATERIALS AND METHODS

A. Sample preparation

The experimental design is shown in Fig.1. Pork loins from 4 pigs were selected. Each loin was deboned and sliced in a total of 5 pieces of similar dimensions: approximately 7 cm thick, 5-6 cm high, and 10 cm long. Each loin was therefore represented in all 5 weight loss groups. The desired weight losses for the different groups were 20, 25, 30, 35 and 40 % loss of initial weight. Generally, dry-cured meat products have 30-35 % weight loss in the final product [7]. In order to achieve a final salt concentration of approximately 5.5 % in the 30 % weight loss group, all pieces were added 3.85 % salt prior to vacuum packing. The pieces were stored vacuum packed for two weeks at 4°C during salting and salt equalization. After salt equalization the pieces were dried (without vacuum) at 12-14°C and 72-74 % relative humidity (RH) to obtain the desired weight losses. When each piece reached the desired weight loss it was vacuum packed and stored at 4°C until microwave measurements were performed.

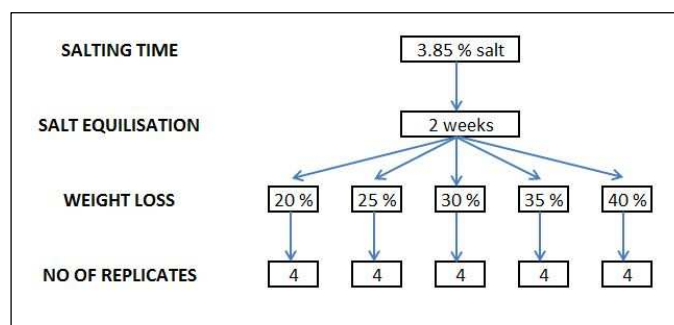


Figure 1. Design of experiment for the dry-cured ham model analysed in this study.

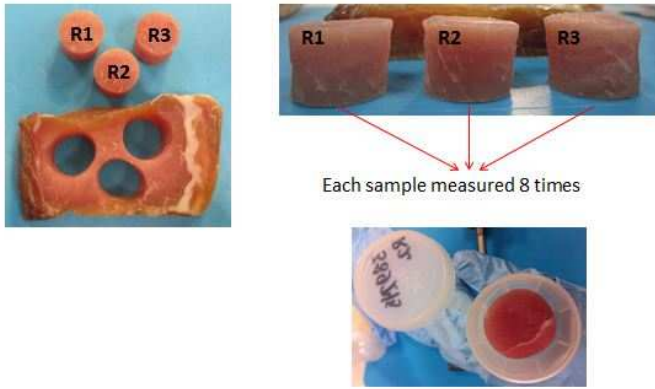


Figure 2. Preparation of samples for microwave analyses. Three replicates from each meat piece were measured eight times.

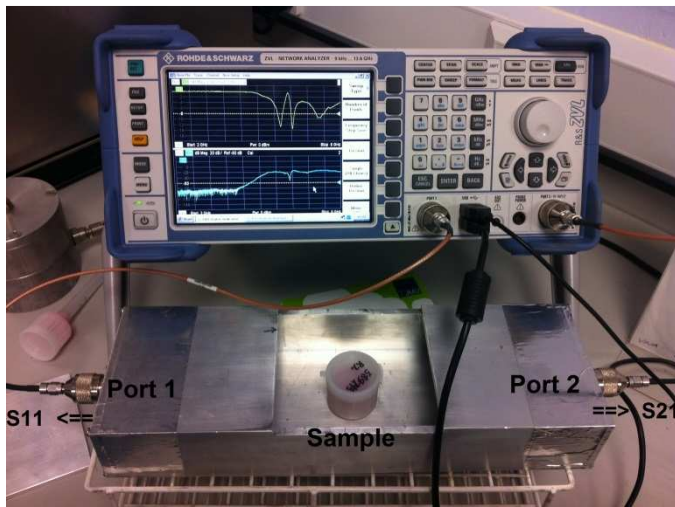


Figure 3. Illustration of the microwave cavity structure, showing where measurements of S_{11} (reflection) and S_{21} (transmission) are required, and position of the sample during measurements.

B. Microwave spectroscopy

Preparation of samples for microwave analysis was performed as shown in Fig.2. A slice of approximately 20 mm thickness was taken from the middle of each dry-cured piece. From this slice, three replicates were taken with a 25 mm diameter borer utilized to cut samples of meat. The meat was then placed into polypropylene tubes with a lid prior to measurements. Each of the three replicates was measured 8 times with 1 hour interval between measurements. The samples were kept at 4°C between measurements.

Measurements of samples were registered at the interval 2-6 GHz. Both the power reflected (S_{11}) from and transmitted (S_{21}) through the sample were registered. The cavity, and the sample position, is illustrated in Fig.3. The same rectangular cavity as designed and used for measuring water holding capacity in raw meat [5] was used in this study.

C. Chemical analysis

Samples for chemical analyses (water activity, sodium chloride and water content) were taken from each meat piece at the same time as samples were analysed using microwave spectroscopy. Water activity was measured by a water activity meter (Aqualab, USA), for all replicates (3) from each of the meat pieces. The water and sodium chloride content were measured by an accredited lab (Eurofins, Norway).

D. Statistical analysis

The data were statistically processed by one-way ANOVA and Tukey's multiple comparisons test at P-value < 0.05 (R Foundation for statistical Computing, version 2.15.2). For statistical analyses on water activity, the mean values for all three replicates from each meat piece were used.

III. RESULTS AND DISCUSSION

Table 1 shows the mean and standard deviation for chemical analyses of dry-cured ham, divided into different groups according to the samples weight losses. The weight loss was calculated from the initial weight of the meat samples. The water activity presented in the Table is the mean value for all three replicates from each piece of dry-cured ham. The results show that as the weight loss increases, the water activity and the water content decrease. In addition, the salt content increases with higher weight loss. These results are in agreement with previous knowledge [6,7]. The water content for the 40 % weight loss group is slightly higher than for the 35 % weight loss group. This might be explained by low differences in final weight loss between these groups, in addition to high variation within the 40 % weight loss group. The salt content for the 30 % weight loss group is slightly higher than expected. This might be explained by differences in the final water content for the samples, the initial water content in the samples was more or less equal.

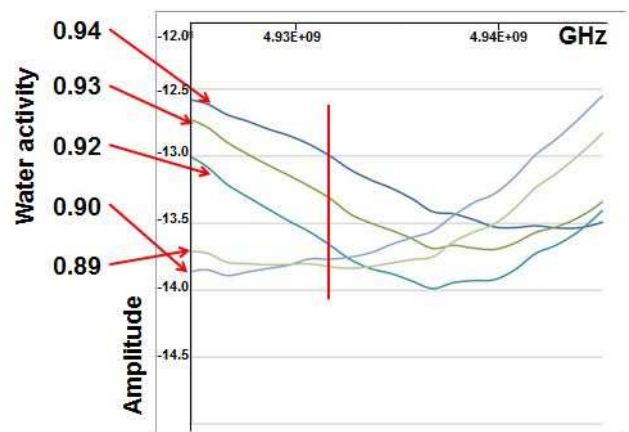


Figure 4. The S_{11} (reflection) spectra for dry-cured meat pieces from one loin (all weight loss groups) at 4.93 GHz (red line). As the amplitude decreases, the water activity decreases as well.

TABLE I. MEAN AND STANDARD DEVIATION FOR CHEMICAL ANALYSIS OF DRY-CURED HAM

Weight loss group	Final weight loss	Water activity (a_w)	Water (g/100 g sample)	NaCl (g/100 g sample)
20 %	20.34±0.90 ^a	0.921±0.021 ^a	53.05±5.44 ^a	5.77±0.71 ^a
25 %	24.65±1.00 ^b	0.917±0.017 ^a	52.83±3.89 ^a	6.20±0.98 ^a
30 %	29.79±1.75 ^c	0.897±0.024 ^{a,b}	48.23±8.28 ^{a,b}	6.83±0.78 ^{a,b}
35 %	32.76±1.75 ^{c,d}	0.865±0.027 ^b	39.30±6.34 ^b	7.49±0.71 ^{a,b}
40 %	34.69±3.63 ^d	0.856±0.027 ^b	41.10±5.10 ^{a,b}	8.13±0.80 ^b

Means within a column with different letters are significantly different (P<0.05)

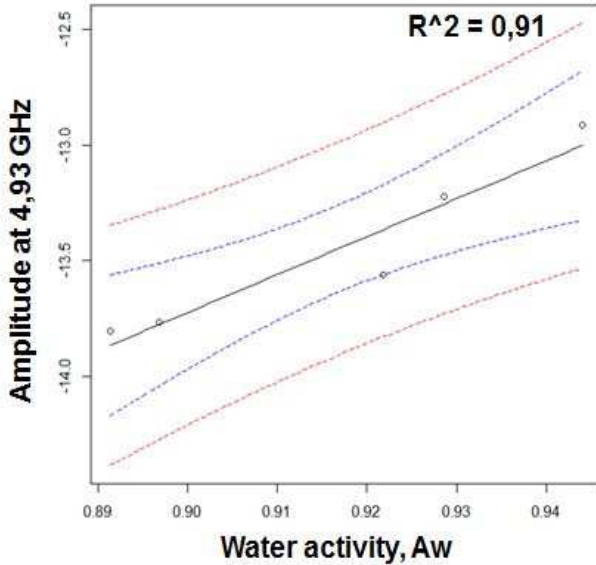


Figure 5. The correlation between the amplitude at 4.93 GHz and the water activity is shown for all weight loss groups from one loin.

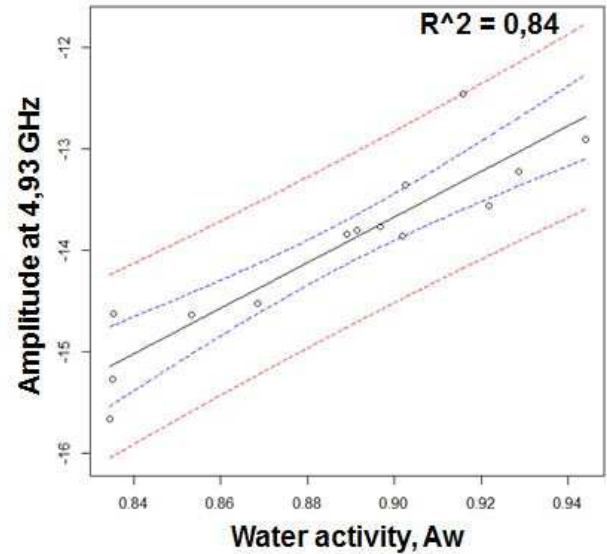


Figure 6. The correlation between the amplitude at 4.93 GHz and water activity is shown for all weight loss groups from all loins.

The S_{11} spectra (reflected) was analysed, and a correlation between water activity and the spectra was observed at approximately 4.93 GHz. Fig.4 shows that with decreasing amplitude the water activity in the dry-cured meat samples also decreases. Given that the water activity decreases with higher weight loss, the amplitude also decreases with increased weight loss of the dry-cured meat samples. The Figure shows results for all five weight loss groups from one loin. The correlation between the amplitude at 4.93 GHz and water activity was 0.91 for this loin (Fig.5). The results indicate that there is possible to separate samples with small differences in water activity using microwave spectroscopy.

The S_{11} (reflection) spectra for all weight loss groups and from all loins, with a few outliers excluded, was also analysed (data not shown). As presented in Fig.5, a correlation was observed between water activity and the spectra at approximately 4.93 GHz (Fig.6). Here, the correlation between the amplitude at 4.93 GHz and the water activity of the dry-cured meat samples was 0.84. These results further confirm

that it is possible to separate samples with different water activities.

The results presented here are the first step in a larger project, and aimed at investigating whether it was possible to predict water activity using microwave spectroscopy. The experiment included only few dry-cured meat samples within each group. For further confirmation of the results presented here, a study analyzing larger experimental groups should be conducted.

IV. CONCLUSION

A shift in amplitude for the S_{11} (reflection) signal was observed between different weight loss groups at a given frequency. This shift was related to water activity, and the correlation with the microwave measurements was up to 0.91. These results indicate that microwave measurements might be a promising technique for determination of water activity for the process control of dry-cured hams. Further studies should include investigation of differences between weight loss groups at more frequencies and also for the S_{21} (transmission) spectra.

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