NA-23 MAGNETIC RESONANCE IMAGES OF SALTED HAMS

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SUMMARY

Magnetic Resonance Imaging (MRI) has been developed to characterize tissues by morphological studies. In the present work, Na-23 NMR imaging was used to study the distribution of brine in ham. For these studies, four pigs (one piglet, three Large White breeds) were used. For the raw meat experiment the images were made 2 and 24 hours after injection of brine (5M NaCl) at 0°C. Brine was injected before the onset of *rigor mortis*. In the second experiment, the images were made on cooked ham and the effect of tumbling was investigated. Images of NaCl diffusion were compared with morphological images obtained with H-1. Thus, it was possible to study the brine diffusion within the ham and to show the heterogeneity of the diffusion in raw ham.

INTRODUCTION

Water holding capacity is enhanced when brine is mixed quickly and thoroughly with the meat in the early pre-rigor state (Goutefongea & Schimann, 1973; Hamm, 1977). There is little documentation on brine diffusion inside muscle (Frøystein et al 1989). Magnetic Resonance Imaging (MRI) is a non destructive method able to give this information. MRI has been developed to characterize tissues by morphological studies. Water and fat content on carcasses or pieces is now easily determined by cross-sectional images (Foster et al 1989). This work deals with the use of Na-23 MRI to study the distribution of brine in ham.

MATERIAL AND METHOD

Animals

For these studies, four pigs (one piglet and three Large White breeds) were used. The pigs were killed by electrostunning and exsanguination.

Raw Meat : The hams were immediately cut from the carcass. Fat and rind were removed and treated as described in table 1. The hams were injected 15% w/w with (5M NaCl) brine cooled at 0°C. The right ham of pig 1 (study N°4) was boned and tumbled for 1 hour.

Cooked hams : All hams were injected as previously described, except the left ham of pig 2 (study N°5), which was cut 24 h *post mortem*.. The no-tumbled hams were placed in the brine (3M NaCl) at 1°C for 24 hours before cooking. The right ham of pig 3 (study N°8) was boned and tumbled for 1 hour and immediately cooked by standard method.

NMR

Experiments were carried out on a Bruker Biospec 47/40 in Bruker Karlsruhe. The magnetic field is 4.7T and the clearance of this horizontal magnet is 40 cm. To obtain Na-23 and H-1 images, a specific 25 cm double-tuned probe operating at 52.9, 200 MHz was designed. The sample size was about 20 x 15 x 8 cm. The 3D-Gradient Echo pulse sequence was chosen for its short time echo and low flip angle hard pulse, Na^+ nuclei having a very short transverse relaxation time (≈10 ms). The H-1 images were obtained in two scans with a matrix 128 x 128 x 128. The field of view was 25 cm^3; the Na-23 images resulted from 8 scans with a matrix 128 x 64 x 64. For the piglet experiment (studies N°1 & 2) the images were obtained 2 hours after injection. In the second set of raw meat experiment (studies N°3 & 4), the images were obtained 24 hours after injection of brine. For cooked hams the images were obtained 2 weeks after cooking.

Table 1

Experiment	Study N°			Brine Injection	Tumbling	Soaking	Cooking Ham
Raw Meat	1	Piglet	Left ham	+			
	2		Right ham	+			
	3	Pig 1	Left ham	+			
	4		Right ham	+	+		
Cooked hams	5	Pig 2	Left ham				+
	6		Right ham	+		+	+
	7	Pig 3	Left ham	+		+	+
	8		Right ham	+	+	+	+

RESULTS AND DISCUSSION

The images can be obtained both in plane (2D) and three dimensions (3D). Images are generated on the basis of data matrices whose elements differ in numerical values. High values are represented by lighter pixels and darker pixels correspond to lower values.

Experiments on raw meat

Figure 1 is a surface reconstruction image and shows the Na images in 3D from a piglet ham (study N°1). The shape of the ham is easily recognized. In Fig 2 the Na^+ diffusion was compared with morphological images obtained with H-1. Fig 2a is a 2D H-1 image. The bones appeared black and the muscles light because of the high water concentration. Fig 2b is a 2D Na-23 image for the same slice as before. The white area corresponded to the highest concentration in Na^+. So, the diffusion of brine was heterogeneous. There was a higher concentration of NaCl in the pathway corresponding to the artery and in a noticeable cluster inside the ham. The brine was therefore heterogeneous.

The tumbling effect was observed in the studies 3 &4. The Fig 3a &3b give 3D Na-23 image of two hams from pig 1. The tumbling was not performed on the ham on the right of the picture. Na^+ were present at the surface of both hams (Fig 3a), almost non existent inside the no-tumbled ham (study N°3) and everywhere in the tumbled ham (Fig 3b). Fig 4a & b depict the same slice for H-1 and Na-23 images through the 3D set of the previous hams. There was no difference between the two hams in the H-1 image (Fig 4a), while Na^+ was almost invisible in no-tumbled ham (Fig 4b) and thus confirming the previous results. However, in Fig 4b, the diffusion of brine appears, once more, heterogeneous for the tumbled hams.

Experiments on cooked hams

Fig 5a & 5b are 2D images of for hams : the ham without brine injection (study N° 5) is shown on the left ; two hams with injection of brine (studies N°6 & N°7) are in the middle and the injected and tumbled ham (study N°8) is on the right . On the Fig 5a, the hams presented no

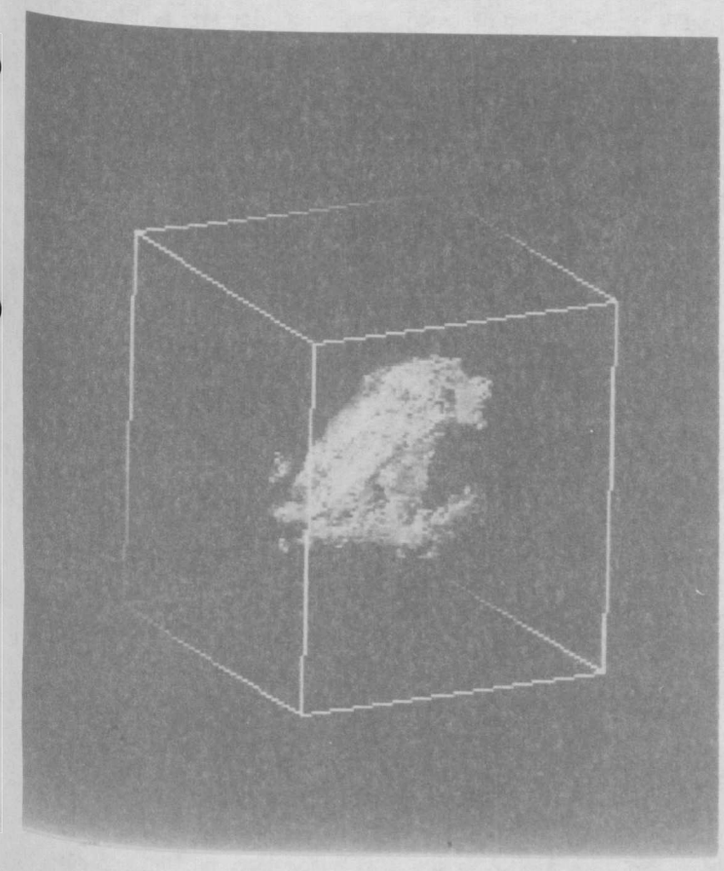

FIG 1 : 3D Na surface reconstruction image from a piglet ham

FIG 2b : 2D Na image from a piglet ham

FIG 2a : 2D H-1 image from a piglet ham

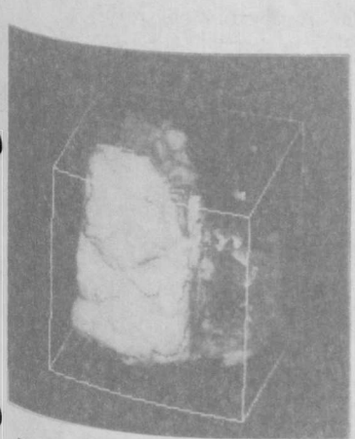

Fig 3b : 3D Na image ; as Fig 3a but surface is cut away

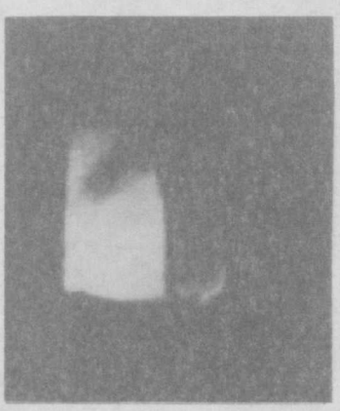

Fig 4b : 2D Na image ; same slice as Fig 4a

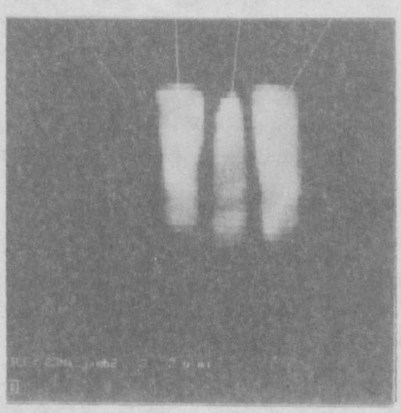

Fig 5b : 2D Na image ; same slice as Fig 5a

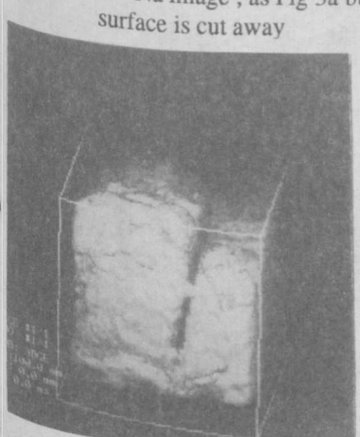

Fig 3a : 3D Na surface reconstructuion image ; on the left churned ham

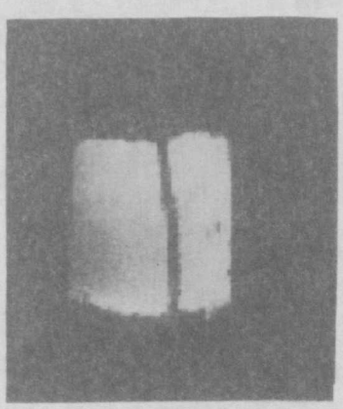

Fig 4a : 2D H-1 image ; on the left churned ham

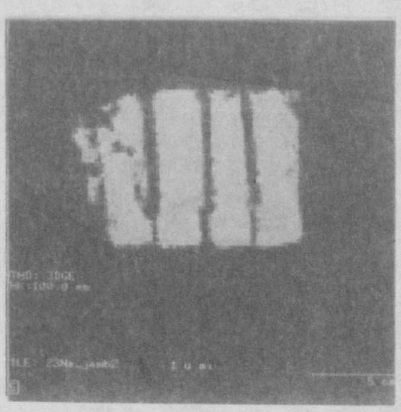

Fig 5a : 2D H-1 image from Paris ham

differences with H-1 imaging. Then, on the Na-23 image (Fig 5b), the ham on the left became invisible (no brine injection -study N° 5), while the three others gave a lot of Na signals. The distribution of Na^+ was uniform inside the meat, regardless of the technological processes. The diffusion of brine inside the meat could be operated during cooking.

CONCLUSION

These results showed a great heterogeneity of diffusion of salt. The arterial injection did not produce the right distribution of salt in the ham. The tumbling enhanced the homogeneity, but still an even salt distribution in the samples was not obtained. However, after cooking the distribution of salt was better. MRI is a powerful method to determine the diffusion of salt in different technological processes. Na-23 Magnetic Resonance Imaging is the method of choice for looking at meat treated with NaCl brine. Na^+ concentration in the tissue can be tracked. In contrast, H-1 Imaging gives no information of that kind but can be useful for the knowledge of brine diffusion according to morphology.

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