Acta Agrophysica, 2007, 9(1), 31-38

RELAXATION INVESTIGATIONS OF FORCEMEATS AND SAUSAGES WITH AN ADDITION OF PLANT FAT

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Abstract. The aim of the performed investigations was to analyse water binding in forcemeats and finely-comminuted sausages manufactured with the addition of plant fat. Comparison of relaxation parameters with values of the free water content in relation to the total water content in sausages showed that plant fat is much better dispersed in the system. The quantity of bound water increases and its molecular dynamics is limited considerably. This exerts a significant impact on the quality of the obtained products. The applied partial replacement of animal fat by plant fat results in increase of free water content in the system, in comparison with products containing only one type of fat.

Keywords: fat, forcemeat, low field NMR, water

INTRODUCTION

The consumer market is interested in products of pro-salubrious nature. Meat articles of the 'hot-dog' type contain high quantities of fat. Attempts to apply substitutes which reduce the fat content, undertaken earlier (Baranowska *et al*., 2003; Baranowska *et al.*, 2004a, Piotrowska *et al*., 2004; Rezler *et al*., 2006), showed that it is not possible to reduce drastically quantities of this component without affecting the quality of the final product. Animal fats contain over 50% of saturated fatty acids (Pikul, 1997). In addition, the content of fatty acids in the animal-derived fats depends, to a large extent, on the way of feeding and, therefore, is difficult to control during the process of sausage production. Current nutritional trends indicate that the content of dietary trans fatty acids should be reduced. At the same time, it is desirable to increase the consumption of unsaturated fatty acids. It is, therefore, advantageous to apply plant-derived fats for the production of food products and these fats are already employed to manufacture pâtés. (Echarte *et al*., 2004; Estevez *et al*., 2004; Estevez *et al*., 2005).

No attempts have been made so far to apply plant fat to manufacture finely-comminuted sausages. The aim of the performed investigations was to analyse qualitatively and quantitatively the conditions of water binding in finely-ground forcemeats and sausages containing plant fat. The studies were carried out employing the technique of low field *NMR*.

MATERIAL AND METHODS

The experimental material comprised forcemeats of finely-comminuted sausages as well as final products in which fine animal fat was replaced either partly or completely with plant fat. The basic raw material composition is presented in Table 1.

Table 1. Sausage raw material composition

Constituent	Content (%)
Pork meat, class lll	48.65
Fat	20.88
Water	27.83
Spices	0.60
NaCl	2.00
Ascorbate	0.04

The following two plant fats were used in the experiments: Acoroma *OM* and Acoroma *LS* manufactured by the Karlshamns Company. These two products differ in the content of fatty acids, which is given in Table 2.

Table 2. Composition of fatty acids

Fatty acids	Content (%)	
	OM	LS
Trans	1	2
Omega-3 (*C18:3 ALA*)	3	5
Omega 6 (*C18:2*)	–	13
Saturated	41	30
Monounsaturated	44	49
Polyunsaturated	15	19

The following 5 variants of forcemeats were prepared: *S* – containing only fine pork fat, *OM* – containing only plant fat Acoroma *OM*, *LS* – containing only plant fat Acoroma *LS*, *OM/S* – containing 50% of Acoroma *OM* plant fat and 50% of pork fat, and *LS/S* – containing 50% of Acoroma *LS* plant fat and 50% of pork fat.

The content of total water was determined in accordance with the Polish standard (Baranowska *et al.*, 2004). A sample of 5 g was weighed (with 0.001 g accuracy) and dried in a drier at the temperature of 105^{o}C for 6 hours. Next, the sample was placed in a desiccator until it reached room temperature and then weighed and placed in a drier again for 1 hour. This operation was repeated until the moment when the weight difference between individual weighings equalled 0.001 g. The content of water was calculated from the following formula:

$$Ww = \frac{(a-b)}{c} \cdot 100 \qquad (1)$$

where: *a* – weight of one portion with filter paper before drying (g), *b* – weight of one portion with filter paper after drying (g), c – weight of the portion (g).

The total water content was determined using the method of Volovinska and Kelman modified by Gracz (Baranowska *et al.,* 2004). Wattman filter paper was cut into squares of 8 cm sides and dried in a drier at the temperature of 80°C for 8 hours. Filter papers prepared in this way were stored in the desiccator. In order to carry out an assay, exactly 0.3 ±0.001 g of forcemeat was placed in the middle of filter paper and covered with foil. Next the sample was placed between glass plates and a load of 1000 g was placed on it. The load was removed after 20 minutes and the size of the blot left by the forcemeat and drip was outlined. The size of the blot was measured using a planimeter.

The content of free water (*Ww*) was determined according to the following formula:

$$Ww = [(a-b) \cdot 1.766] \cdot 100\% \qquad (2)$$

where: *a* – surface area of the drip stain (cm^2), *b* – surface area of the forcemeat stain (cm^2), 1.766 – calculation coefficient.

The spin-lattice T_1 and spin-spin T_2 relaxation times were measured on a pulse *NMR* spectrometer working at 30 MHz. Measurements of T_1 were performed by using the inversion-recovery pulse sequence (π–τ–$\pi/2$) (Fukushima *et al*. 1981), the distance between *RF* pulses (τ) varied from 4 to 2400 ms, repetition time 10 s. During the measurements, 32 *FID* signals were recorded. The number of points in the signal amounted to 110.

Spin-spin T_2 measurements were performed by using a *CPMG* pulse train (Carr *et al*., 1954; Meiboom *et al*., 1958), with the distance between the pulses at 2 ms, the number of spin echoes was 50. In the measurements, 5 accumulations were applied. The measurements were performed at +20°C.

The values of T_1 were calculated from the formula:

$$M_z = M_0\left(1 - 2\exp\left(\frac{-\tau}{T_1}\right)\right) \qquad (3)$$

where: M_0 and M_z are the equilibrium and transient values of magnetisation, with the program CracSpin (Węglarz *et al*., 2000). Only one relaxation time value was found for all the samples.

The spin-spin relaxation time, T_2, was calculated from the fit with the formula (Baranowska *et al*., 2003; Baranowska *et al*., 2004a; Bertram *et al*., 2002):

$$M_{x,y} = \sum_{i=1}^{n} p_i \exp\left(\frac{-TE}{T_{2i}}\right) \quad (4)$$

where: p_i is the fraction of protons relaxing with T_{2i} time.

Two fractions of protons were found relaxing with different T_2 times in all studied samples.

RESULTS AND DISCUSSION

The content of water in the finished products was analysed. This parameter was determined as the ratio of free water to the total water content. The obtained results are presented in Figure 1.

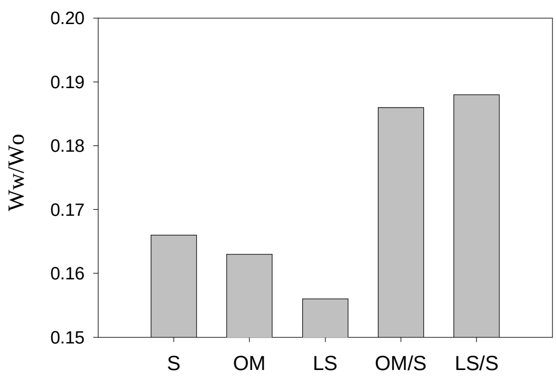

Fig. 1. Relative water content in sausages

Systems in which part of the animal fat has been replaced by plant fat are characterised by a high content of free water in relation to the total water content. This high free water content may indicate that the application of both types of fat removes water from the surface of proteins and water contained in the fat tissue as a result of thermal treatment. The reduction of the relative free water content in systems containing plant fat indicates the development of emulsions and immobilisation of part of water.

Relative quantitative proportions between the content of free water and bound water are analysed on the basis of the results of the spin-lattice T_1 relaxation times. Figure 2 shows value changes of this relaxation time for individual forcemeats and sausages.

Differences in the T_1 values for individual forcemeats were found. Identical results were recorded in the samples from the final products. The total replacements of animal fats by plant fats reduced the T_1 values both in forcemeats and in the finished products. The best water binding was found when the *LS* fat was employed. The application of both types of fats – animal and plant – caused that in forcemeats the T_1 values were much higher than those obtained for forcemeats and sausages containing only one type of plant fat or in forcemeats which contained only animal fat. Water present in a system which contains animal fat is weakly bound. The thermal treatment applied to forcemeats reduced the T_1 values due to protein denaturation (Baranowska *et al.*, 2004). Water molecules are bound in sorption places exposed by denaturation.

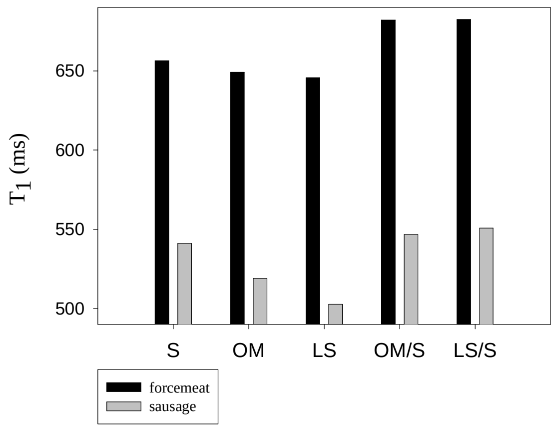

Fig. 2. T_1 values in the examined forcemeats and sausages

The obtained results show that the application of plant fat to manufacture finely-comminuted sausages allows obtaining products characterised by better water binding already at the stage of forcemeat preparation. In addition, it can also be said that plant fat is better dispersed in the multi-phase system and, consequently, water molecules bind with muscle proteins with no competition from proteins contained in the fat tissue. The application of two types of fats in the production of finely-ground sausages caused a significant reduction of water binding.

The quantitative description of mutual proportions between free and bound water can be supplemented by analysis of the molecular dynamics of water molecules in both fractions (Baranowska *et al.*, 2003; Baranowska *et al*., 2004a). Values of relaxation times describing the dynamics of bound water molecules are presented in Figure 3. A shortening of the spin-spin relaxation times in systems containing only plant fat is observed in comparison with the remaining systems. Simultaneously, the replacement of part of animal fat in forcemeats by plant fat reduced the values of this relaxation time.

In the case of systems containing animal fat, there is little bound water and it is dynamic. This may indicate a considerable lability of binding of water molecules with muscle proteins. The utilisation of plant fats guarantees a significant reduction of the molecular dynamics of this water fraction and, hence, the water binding is stronger and more stable.

Values of the T_{22} spin-spin relaxation time presented in Figure 4 reflect the dynamics of free water molecules.

Free water was the most mobile in the forcemeats and final products containing animal fat. The application of plant fat reduced the value of this parameter, indicating restriction of molecular dynamics of free water in the system. The application of only plant fat ensured not only a reduction of free water in relation to bound water but also inhibited its dynamics. The performed investigations revealed that the utilisation of plant fats improved significantly water binding parameters.

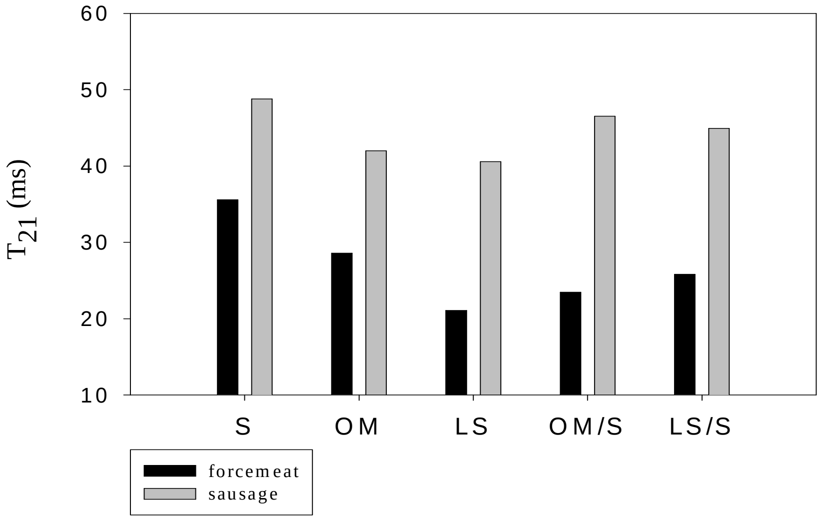

Fig. 3. Values of T_{21} in the examined forcemeats and sausages

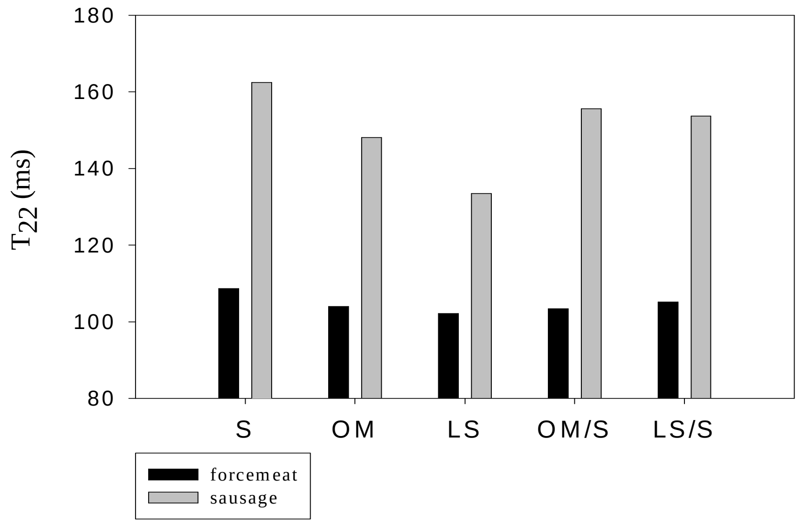

Fig. 4. Values of T_{22} in the examined forcemeats and sausages

In the case of the forcemeat which contained only animal fat, water is bound primarily on the surface of myofibril proteins which are constituents of meat. The replacement of animal fat by plant fat causes that the excess of water, not connected with meat components, forms emulsions and limits the amount of free water as well as its dynamics. Both the relaxation measurements and the determination of the relative content of free water in relation to the total water content indicate that the addition of plant and animal fats results in very weak water binding and, consequently, deterioration of the quality parameters already at the stage of forcemeat preparation. This may have a negative impact on the rheological parameters of the final products and may cause considerable thermal drip.

CONCLUSIONS

1. The replacement of animal fat by plant fat characterised by higher salubrious properties in the production of finely-ground sausages improves the quality of the products.

2. The employment of plant fat to manufacture finely-comminuted sausages reduces the content of free water in the system in comparison with systems containing animal fat.

3. Molecules of free and bound water in systems containing plant fat are characterised by limited mobility and develop more stable bonds.

4. The simultaneous addition to forcemeats of animal and plant fats increases considerably the amount of free water in relation to bound water in the system.

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BADANIA RELAKSACYJNE FARSZÓW I WĘDLIN Z DODATKIEM TŁUSZCZU ROŚLINNEGO

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S t r e s z c z e n i e. W pracy analizowano wiązanie wody w farszach i wędlinach drobno rozdrobnionych, wyprodukowanych z dodatkiem tłuszczu roślinnego. Porównanie parametrów relaksacyjnych z wartościami zawartości wody wolnej w stosunku do ogólnej zawartości wody w wędlinach wykazało, że tłuszcz roślinny jest dużo lepiej dyspergowany w układzie. Wzrasta ilość wody związanej, a jej dynamika molekularna jest znacznie ograniczona. Ma to istotny wpływ na jakość uzyskanych produktów. Częściowa zamiana tłuszczu zwierzęcego na roślinny powoduje wzrost zawartości wody wolnej w układzie w porównaniu do wyrobów zawierających tylko jeden rodzaj tłuszczu.

S ł o w a k l u c z o w e: tłuszcz, farsz, magnetyczny rezonans jądrowy, woda