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THE EFFECT OF HYDRATION OF A PROTEIN PREPARATION ON THE STATE OF WATER IN FINE FORCEMEAT SAUSAGES

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A b s t r a c t. The study was undertaken to establish changes in water binding in fine forcemeat with some of the meat substituted by the protein preparation CC 400. Three different variants of hydration of the preparation were tested: 1:5, 1:7.5 and 1:10. At each level of hydration the meat was substituted in 5%, 10% and 15% of that in the initial state (reference sample). The content of total and free water was determined along with the spin-lattice and spin-spin relaxation times. The forcemeat was subjected to thermal treatment and the amount of thermal drip was measured. The degree of hydration of the protein preparation was found to determine the mutual relations between the free and bound water in the forcemeat and the molecular dynamics of water. The greatest amount of bound water and the smallest thermal drip were obtained for the protein preparation hydration at the ratio 1:7.5. Higher hydration can only be used at 5% meat substitution. The samples with 15% meat substitution should be hydrated at 1:5 ratio.

Key words: forcemeat, low field NMR, protein preparation, water

INTRODUCTION

The use of non-meat additives in meat products has become a daily practice for both technological and economical reasons. Fine forcemeat sausages have been in high demand for many years and for a few years work is continued on getting products with optimum physico-chemical properties [1,7,12,15]. The additives tested include cellulose, starch and proteins [1,2,3,8,10]. Protein preparations used as meat substitutes are known to improve the sensory character-ristics and to enhance the nutritive value of the products, mainly because of their ability of emulsification, fat absorption, water absorption and retention.

The paper reports results of a study on fine forcemeat with additions of the protein preparation CC 400 at different degrees of hydration. Changes in the water content and its dynamics were analysed versus the degree of hydration and proportion of meat substitution.

MATERIALS AND METHODS

The study was performed on forcemeat samples with different degrees of hydration and different amounts of CC 400 replacing meat. The reference sample was the forcemeat sample of the composition given in Table 1.

Table 1. The reference sample composition

Component	Content (%)
Pork Meat, 3rd Class	48.71
Fine Fat	20.88
Water	27.83
Curring Mixture	0.97
Nacl	0.97
Seasonings	0.58
Sodium Ascorbinate	0.06

The meat additive used was the preparation CC 400 made by Inter JJP, Poznań, containing 91% protein including 70% collagen. It is characterised by high water retention and it is a good emulsifier. According to the producer's recommendation it is used only for meat products.

The protein preparation CC 400 was hydrated at the ratio of 1:5: 1:7.5 or 1:10 and the hydrated preparation was used to replace 5%, 10% or 15% from the initial meat content. As follows from the above procedure, the amount of water in the additives increased and the amount of water added in particular samples is given in Table 2.

Table 2. The proportion of water added to forcemeat with the added protein preparation CC400 of different degree of hydration, for forcemeat samples with different proportions of meat substitution

Degree of hydration	Meat substitution			
	Control	5%	10%	15%
1:5	27.8	30.26	32.68	35.05
1:7.5	27.8	31.18	34.42	37.52
1:10	27.8	32.09	36.09	39.84

In order to analyse the binding of water in forcemeat samples of modified composition, the fundamental parameters describing the amount and strength of water binding were determined, such as the total water content, free water content, thermal drip and spin-lattice and spin-spin relaxation times.

The total water content was determined by drying [1] and calculated from the formula:

$$W_0 = \frac{a-b}{c} \cdot 100\% \tag{1}$$

where: *a* and *b* are the masses of the sample with blotting paper before and after drying and *c* is the mass of the blotting paper.

The content of free water was determined by the method proposed by Volovinska and Kelman [13] and calculated from the formula:

$$W_w = (a-b) \cdot 1.766 \tag{2}$$

where: *a* and *b* are the areas of the drip spot and the forcemeat spot, and 1.766 is a correction factor.

The volume of thermal drip (W_c) was measured while heating an accurately weighted forcemeat portion placed in a cell at 70°C for 30 minutes [9].

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 inversion–recovery pulse sequence (π–τ–$\pi/2$) [6], distance between *RF* pulses (τ) varied from 4 to 2400 ms, repetition time 10 s. During measurements 32 *FID* signals were recorded. The number of points in the signal amounted to 100.

Spin-spin T_2 measurements were performed by using a *CPMG* pulse train [5, 11], with the distance between the pulses 1 ms, the number of spin echos was 100. In the measurements 5 accumulations were applied. The measurements were performed at +20°C.

The values of T_1 were calculated from the formula:

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

where: M_0 and M_z are the equilibrium and transient values of magnetisation, with the program CracSpin [14]. 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 [1,4]:

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

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 the samples studied.

RESULTS AND DISCUSSION

The replacement of some part of meat in forcemeat with a protein preparation requires an addition of water.

The total water content in the forcemeat samples studied determined by drying is displayed in Figure 1.

In all the samples with modified composition the total content of water was higher than in the control sample. In the samples with addition of CC 400 hydrated at 1:5 the total content of water increased linearly with increasing meat substitution. From among the samples with CC 400 hydrated at 1:7.5 or 1:10, the greatest amount of total water was found in those with 10% meat substitution. No significant differences were found in the total water content in the samples with 5% and 15% meat substitution, for all degrees of CC 400 hydration. The hydration of CC 400 at 1:7.5 also did not change the total water content in the samples with 10% and 15% meat substitution, although it was higher than in the samples with 5% meat substitution.

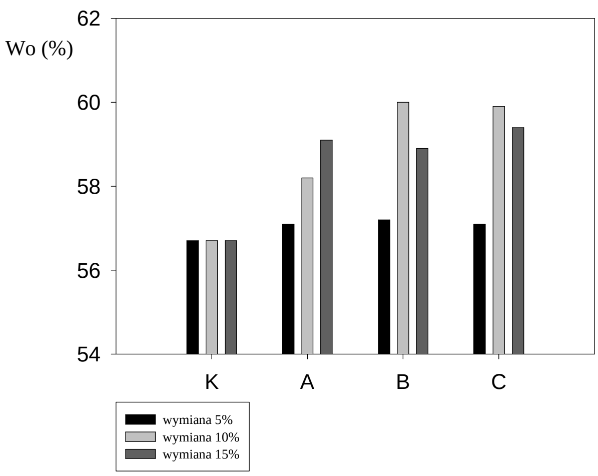

Fig. 1. Total content of water in the forcemeat samples studied versus the degree of hydration of the protein preparation (*K* – control, *A*, *B* and *C* correspond to hydration at 1:5, 1:7.5 and 1:10)

The content of free water in the systems studied is shown in Figure 2.

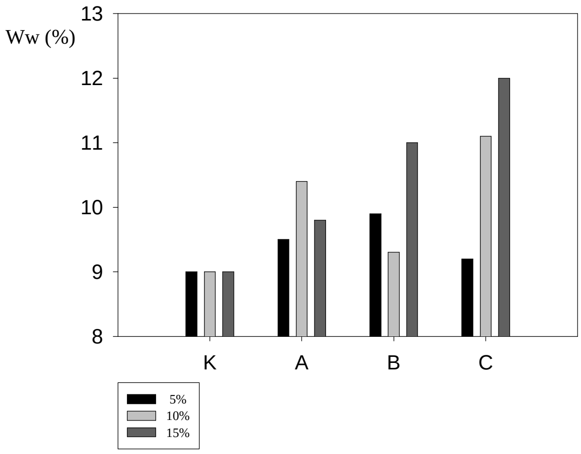

Fig. 2. The content of free water in the forcemeat samples studied versus the degree of CC 400 hydration (*K* control, *A*, *B* and *C* correspond to hydration degrees of 1:5, 1:7.5, 1:10

In all forcemeat samples with modified composition the content of free water was higher than in the control sample. In the samples with CC 400 hydrated at 1:10 an increase in the free water content with increasing proportion of meat substitution was observed. In the samples with CC 400 hydrated at 1:7.5 the content of free water was the lowest at 10% meat substitution and the highest at 5% meat substitution.

The relationship between the content of free and total water was analysed, see Figure 3.

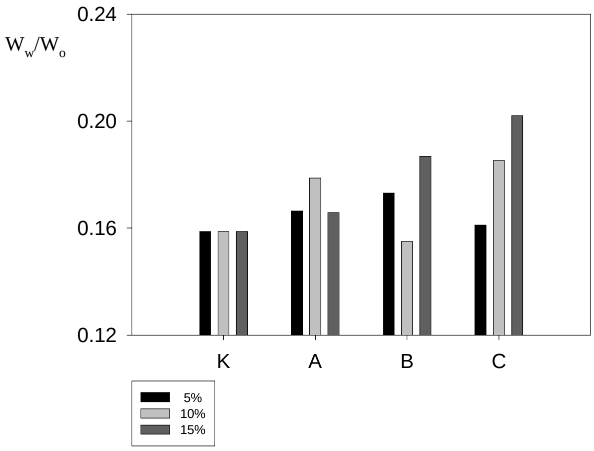

Fig. 3. The content of free water relative to that of total water in the forcemeat samples for different degrees of CC 400 hydration (K control, A, *B* and *C* correspond to CC 400 hydration at 1:5, 1:7.5 and 1:10, respectively)

The relative water content was the lowest in the samples with CC 400 hydration at 1:7.5 and 10% meat substitution. The relative water content in this sample was even slightly lower than in the control sample. The highest relative water content was found in the sample with CC 400 hydration at 1:10 and 15% meat substitution.

The above parameters describe the macroscopic state of water in forcemeat, however, they do not bring information on the binding of water and interactions between water and other components.

The spin-lattice relaxation time T_1 depends on relative proportions between the free and bound water. The changes in T_1 time versus the degree of CC 400 hydration in the forcemeat samples studied are shown in Figure 4.

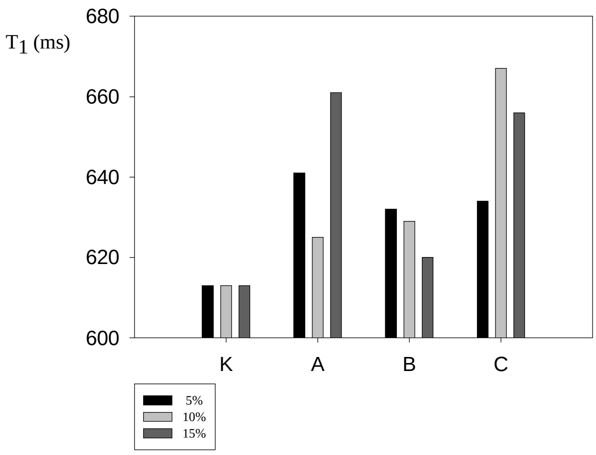

Fig. 4. The spin-lattice relaxation time T_1 of the forcemeat samples versus the CC 400 hydration degree (*K* control, *A*, *B* and *C* correspond to hydration at 1:5, 1:7.5 and 1:10)

The T_1 relaxation time in the samples of modified composition was longer than in the control sample, which was directly related to the introduction of additional amounts of water to hydrate the CC 400 preparation, replacing a certain proportion of meat. The longest T_1 time was found for the sample with CC 400 hydrated at 1:10 and for 10% meat substitution. For the samples with CC 400 hydrated at 1:7.5 the values of T_1 decrease with increasing meat substitution. The lowest T_1 was observed for the sample with CC 400 hydrated at 1:7.5 and with 15% meat substitution, which means that in this sample the content of bound water to that of free water was the greatest. In the samples with 5% and 15% meat substitution, the values of T_1 were the lowest for CC 400 hydration at 1:7.5. In the sample with 10% meat substitution the values of T_1 were insignificantly greater than those in the sample with 5% meat substitution.

The spin-spin measurements revealed the presence of two fractions of water in the samples studied [1,2,12]. The short component of the spin-spin relaxation time T_{21}, corresponds to the relaxation of protons in the bound water fraction, while the long component T_{22} corresponds to the relaxation of protons in free water. Figures 5 and 6 present the spin-spin relaxation times of bound and free water fractions versus the hydration degree of CC 400 replacing certain proportion of meat in the forcemeat samples studied.

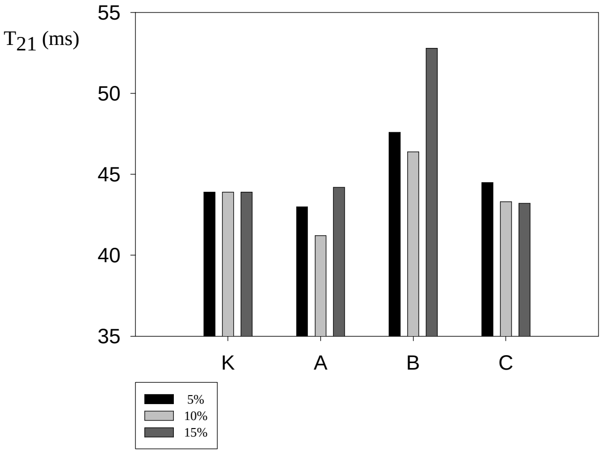

Fig. 5. The short component of spin-spin relaxation time T_{21} in the forcemeat samples studied versus the degree of CC 400 hydration (*K* control, *A*, *B* and *C* correspond to hydration at 1:5, 1:7.5 and 1:10, respectively)

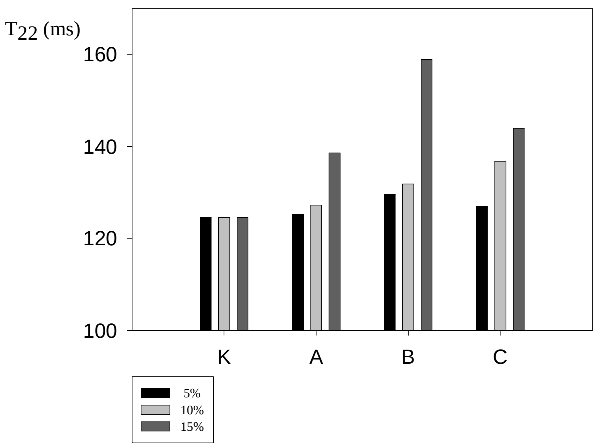

Fig. 6. The long component of spin-spin relaxation time T_{22} in the forcemeat samples studied versus the degree of CC 400 hydration (*K* control, *A*, *B* and *C* correspond to hydration at 1:5, 1:7.5 and 1:10, respectively)

For the samples with CC 400 hydrated at 1:10 no changes in T_{21} relative to that in the control sample were observed. A small increase in T_{21} was noted only in the sample with 5% meat substitution. For the samples with CC 400 hydration at 1:5 the changes in T_{21} were insignificant. Only in the samples with 10% meat substitution a small shortening in T_{21} was observed relative to that in the control sample. A significant increase in T_{21} and differentiation of its values were noted for the samples with CC 400 hydrated at 1:7.5, the lowest T_{21} value was obtained for 10% meat substitution.

The values of T_{22} time were higher in all samples with modified composition relative to that for the control sample. For the samples with each CC 400 hydration degree, the values of T_{22} increased with increasing meat substitution. The longest T_{22} was observed for the samples with 15% meat substitution and CC 400 hydration at 1:7.5. In the samples with CC 400 hydrated at 1:5 and 1:7.5 and with 5% and 10% meat substitution, the T_{22} time was not significantly different.

The samples studied were subjected to thermal treatment to establish the amount of drip. The results are presented in Figure 7.

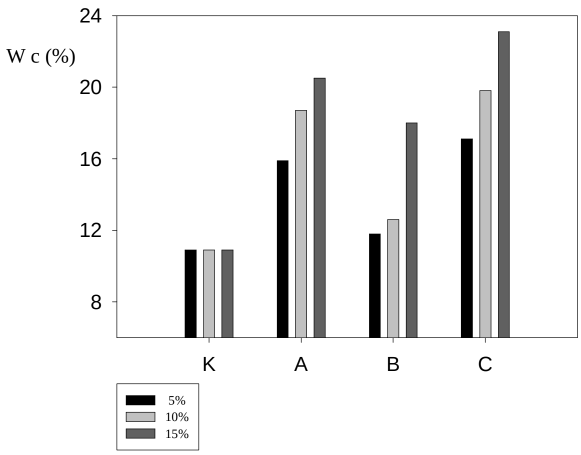

Fig. 7. The volume of the thermal drip in the forcemeat samples studied versus the degree of CC 400 hydration (*K* control, *A*, *B* and *C* correspond to hydration at 1:5, 1:7.5 and 1:10, respectively)

The thermal drip of all the samples studied with modified composition was greater than that of the control sample. The volume of the drip increased with increasing meat substitution. The smallest drips were noted for CC 400 hydrated at 1:7.5.

Macroscopic analysis of the state of water in the forcemeat samples studied has shown that the degree of CC 400 hydration does not change the total water content in the samples with 5% and 15% meat substitution. In the samples with 10% meat substitution no differences were found in the total water content for CC 400 hydration at 1:7.5 and 1:10. A relation between the CC 400 hydration degree and the free water content in the forcemeat samples studied was found. In the sample with CC 400 hydrated at 1:7.5 the relative content of water (W_w/W_o) was lower than for the control sample, at 10% meat substitution.

Results of the *NMR* study provided qualitative (T_1) and quantitative (T_2) information on the free and bound water in the forcemeat samples studied. The greatest bound water content was found in the samples with CC 400 hydrated at 1:7.5. At this degree of CC 400 hydration the bound water was more mobile. The free water mobility did not change with CC 400 hydration degree in the samples with 5% meat substitution. For the samples with CC 400 hydrated at 1:7.5, the thermal drip observed was the smallest.

CONCLUSIONS

1. The degree of CC 400 hydration determines the content of free and bound water in the forcemeat with CC 400 addition and the mobility of the water molecules in these two fractions.
2. Addition of CC 400 hydrated at 1:7.5 ensures correct water binding in the forcemeat samples studied and a small thermal drip.
3. Addition of CC 400 hydrated at 1:10, recommended by the producer, in the samples with meat substitution above 5% is responsible for total water content and large thermal drip.
4. As follows from our results, in the samples with 15% meat substitution the hydration degree of CC 400 should be 1:5.

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WPŁYW UWODNIENIA PREPARATU BIAŁKOWEGO NA STAN WODY W FARSZU WĘDLIN DROBNO ROZDROBNIONYCH

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Streszczenie. W pracy analizowano zmiany związania wody w farszach wędlin drobno rozdrobnionych z dodatkiem preparatu białkowego CC 400 jako substytutu części mięsa. Zastosowano trzy różne warianty hydratacji preparatu: 1:5, 1:7,5 oraz 1:10. Przy każdym uwodnieniu wymieniano 5%, 10% i 15% mięsa ze składu podstawowego. Wykonano oznaczenia ogólnej zawartości wody w farszach i zawartości wody wolnej. Wykonano również pomiary czasów relaksacji spin-sieć i spin-spin. Farsz poddano obróbce termicznej i oznaczono wielkość wycieku cieplnego. Stwierdzono, że sposób hydratacji preparatu białkowego decyduje o wzajemnych relacjach między ilością wody wolnej i wody związanej w farszach oraz o jej dynamice molekularnej. Najwięcej wody związanej i najmniejszy wyciek cieplny zanotowano przy zastosowaniu uwodnienia preparatu białkowego w stosunku 1:7,5. Większe uwodnienie może być stosowane jedynie przy 5% wymianie mięsa. W przypadku dużej, 15% wymiany mięsa hydratowanym preparatem białkowym należy uwodnić go w stosunku 1:5.

Słowa kluczowe: farsz, MRJ, preparat białkowy, woda