Acta Agrophysica, 2003, 2(2), 293-300

EVALUATION OF THE EFFECT OF THE SUBSTITUTION OF FAT FOR PEA CELLULOSE ON THE WATER BINDING STATE IN SAUSAGE FORCEMEAT

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Abstract. The aim of the investigations conducted was to analyze the water binding state in fine sausage forcemeat, produced with differing proportions of rehydrated pea cellulose as a substitute for fat. The apparent viscosity and spin-lattice and spin-spin relaxation times were measured. The result obtained from the viscosity measurements suggests that in the case of the application of pea cellulose as a fat substitute, a replacement of 10% should not be exceeded. The results obtained from the spin-spin T_2 relaxation time measurements show that the water is in two fractions in the systems: bound water and free water. The replacement of some of the fat with pea cellulose causes an interaction of the fat emulsion with the cellulose fibers, which facilitates good binding in the forcemeat. However, too high a fat substitution leads to a situation in which the interaction of water with the cellulose is predominant, with no participation of the fat emulsion. The forcemeat is then characterized by a lower apparent viscosity as a result of the excess of weakly bound water.

Keywords: pea cellulose, fat, forcemeat

INTRODUCTION

The production of new foodstuffs requires the application of a wide set of functional substances facilitating the development of quality in the product. Producers offer an enormous range of additives, which excellently imitate and replace both the meat and the fat in food products of animal origin [1,8,11].

Food producers increasingly tend to develop new production technologies, making it possible to obtain foodstuffs with a reduced fat content, and thus – with low energy value. This stems, among other things, from the growing requirements on the part of consumers in terms of the quality and nutritive value of foodstuffs, including meat products.

The properties of the final product depend on the appropriate proportions and interactions which take place between the main components of the meat filling. These interactions, among which the most important are protein-water, protein-fat and protein-protein, not only determine the water binding capacity and the stability of the emulsion, but also the rheological properties of the meat filling and the texture of the final product [5].

For this reason, the meat and fat substitutes applied should meet specific requirements, making it possible to obtain a product with the same high quality as the product with the traditional formulation. Thus, it is of the utmost importance to determine the state of the water in forcemeat produced with the addition of cellulose preparations [2,6,7].

The aim of the investigations conducted was to analyze the water binding state in sausage forcemeat, produced with differing proportions of rehydrated pea cellulose as a substitute for the fat.

MATERIAL AND METHODS

The experimental material consisted of model forcemeat, in which some of the fat had been substituted with a pea cellulose preparation. The investigations were conducted in the following variants: "0"- forcemeat with no cellulose added, "1", "2", "3" – forcemeat in which 10%, 15% and 20% of fat had been replaced with pea cellulose previously rehydrated in the amount of one part of preparation to four parts of water. The basic formulation composition is presented in table 1.

Table 1. The basic formulation of the forcemeat investigated (%)

Composition	Pea cellulose (%)			
	0	10	15	20
Pork grade III	50.0	50.0	50.0	50.0
Water	28.6	30.3	31.2	32.0
Fine fat	21.4	19.3	18.2	17.1
Pea cellulose	0.00	0.4	0.6	0.9

The pea cellulose - ID 90 - (ID FOOD IDIRC) applied in the experiment exhibits – among other things – a water binding capacity and improves the texture of the products. The average composition of the dry pea cellulose: total dietary fiber: 89%, starch and other sugars: 3%, proteins: 5%, minerals: 3% [9].

In order to measure apparent viscosity, 50 g forcemeat samples were collected and placed directly in a measuring cylinder. The measurements of apparent viscosity were conducted with a rotational viscosimeter Rheotest 2 type RV, using the shear speed D = 1 [s^{-1}] [4]. The values of apparent viscosity η were calculated by using the following formula:

$$\eta = \frac{\tau}{\gamma} \tag{1}$$

where: γ is the shear speed, shearing stress τ is calculated on the basis of the dependency: $\tau = Z \times \alpha$ (z – apparatus constant 86 [N m^{-2} Skt^{-1}], α – torsion angle [Skt]).

To measure relaxation times, samples were collected immediately after the completion of the chopping process and were placed in airtight measuring test-tubes. The measurements of spin-lattice relaxation times T_1 and spin-spin relaxation times T_2 were performed using an NMR pulse spectrometer operating at 30 MHz. Relaxation times T_1 were measured using the inversion-recovery pulse sequence and they were calculated using the following formula:

$$M_z = M_0\left[1 - 2\exp\left(\frac{-TI}{T_1}\right)\right] \tag{2}$$

where: M_z and M_0 are the actual and equilibrium magnetization values, respectively and TI is the distance between the RF pulses. The calculations were performed using the 'CracSpin' program [12].

To measure relaxation times T_2, CPMG [3, 10] pulse trains were used and the times were calculated according to the formula:

$$M_{x,y} = M_0 \exp\left(\frac{-TE}{T_2}\right) \tag{3}$$

where: $M_{x,y}$ and M_0 are actual and equilibrium values of spin echo amplitudes, and TE is the distance between spin echoes.

RESULTS AND DISCUSSION

Changes in the apparent viscosity of the forcemeat with the addition of pea cellulose were analyzed in the study. It was found that only variant "1" of the experiment, in which fat substitution with cellulose was the smallest, exhibits a significant increase in the apparent viscosity of the system in comparison to the control sample. The 10% increase of the substitution induced a decrease of the apparent viscosity. Thus a good binding of the individual components of the system was observed on a macroscopic scale; the binding was in actual fact better than in the control sample,

Changes in the values of the apparent viscosity of the forcemeat investigated are presented in figure 1.

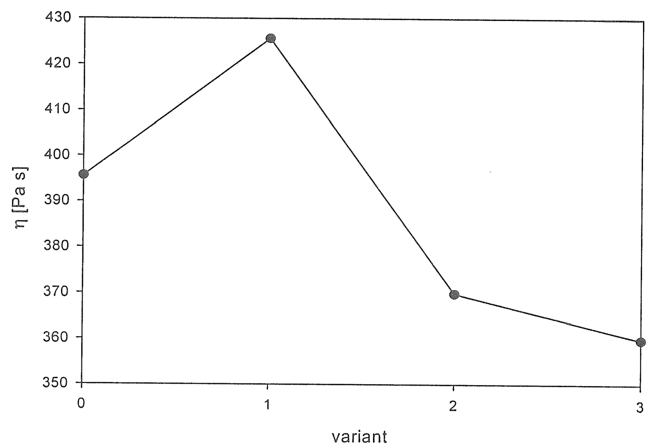

Fig. 1. Changes in values of the apparent viscosity of the forcemeat

In the case of the 10% substitution, very high viscosity of the system was observed. The next variants of the experiment showed a steady drop in the values of viscosity in comparison to non-modified forcemeat, as well as in the function of the amount of fat replaced with rehydrated cellulose. In the experiment discussed here, along with the increase in the amount of added cellulose, the amount of water in the system grew. The effect of the decrease in viscosity is a result of the increase in the water content, which causes a decrease in the density of the forcemeat. However, the significant increase observed in the viscosity in the case of variant "1" may be caused by the specific action of the fat and cellulose in the proportions applied. The amount of cellulose contained in this variant, in spite of the increase in the water content, is sufficient to have the system strongly bound macroscopically and may in the end cause an increase in sausage toughness. The result obtained from viscosity measurements suggests that in the case of the application of pea cellulose as a fat substitute, a replacement of 10% should not be exceeded.

Apart from the macroscopic parameter characterizing the state of the forcemeat (viscosity) in the variants of the experiment investigated, measurements of spin-lattice relaxation times and spin-spin relaxation times were conducted in order to analyze the dynamic state of water in the forcemeat.

Changes in the values of spin-lattice relaxation times T_1 for individual variants are presented in figure 2. It was found that both the forcemeat with no cellulose added and the modified forcemeat are characterized by one relaxation time T_1.

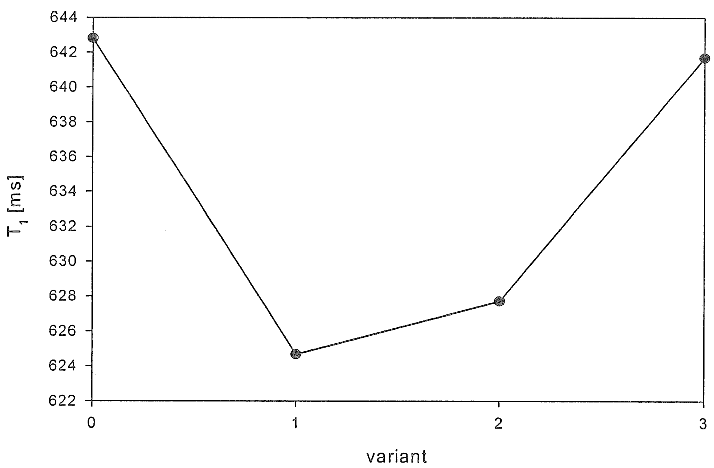

Fig. 2. Changes in the values of spin-lattice relaxation times in the forcemeat

The addition of cellulose results in a reduction of relaxation time. Along with the increase in the content of rehydrated cellulose, spin-lattice relaxation times extend. For the system with the maximum, i.e. the 20% substitution of cellulose for fat, the values of this parameter are similar to those which are obtained for the control forcemeat. The results obtained using this method suggest that the addition of cellulose limits the movement of water molecules. The lowest values were observed for the 10% substitution. Such a drastic reduction in relaxation time T_1 in this system is caused by the strong binding of water molecules, primarily as a result of the effects of the cellulose-fat interaction, observed macroscopically. Further substitution results in an extension of relaxation time as a result of the increase in the water content.

Moreover, changes in the values of the T_2 spin-spin relaxation times were also analyzed. It was found that the system investigated is characterized by the doubly exponential loss of spin echo amplitudes. Thus, two fractions of protons relaxing with different T_2 times are found in the system. The values of these relaxation times were calculated, along with the share of both proton fractions in the spin-spin relaxation process. The T_2^{-1} spin-spin relaxation rate observed is described by the dependency:

$$\frac{1}{T_2} = \frac{1}{T_{21}} + \frac{1}{T_{22}} \tag{4}$$

Using the results of the direct measurements obtained and using the formula at (4), the values of both relaxation times were determined for the systems investigated (fig. 3). A reduction in the relaxation times of both components was found for forcemeat with the addition of cellulose in comparison to the value for the control forcemeat. This is confirmed by the lowering of water dynamics as a result of the addition of cellulose, observed in the T_1 analysis. The short component T_{21} does not change its value in all the variants of the experiment, in which some of the fat is replaced with cellulose. Thus, it is the fraction of bound water present in the fat system and re-hydrated cellulose interacting with it. The drop in the T_{21} values observed is connected with a lowering of the fat content. The results obtained indicate that in the fat-cellulose system, a specific interaction between these components took place. The long component T_{22} corresponding to the relaxation of free water increases along with the increase in the addition of cellulose and – at the same time – the water content.

The replacement of some of the fat with pea cellulose causes an interaction of the fat emulsion with the cellulose fibers, which facilitates the good binding of the forcemeat. However, too high a fat substitution leads to a situation in which the interaction of water with cellulose begins to predominate, with no participation of the fat emulsion. The forcemeat is then characterized by lower viscosity as a result of an excess of weakly bound water.

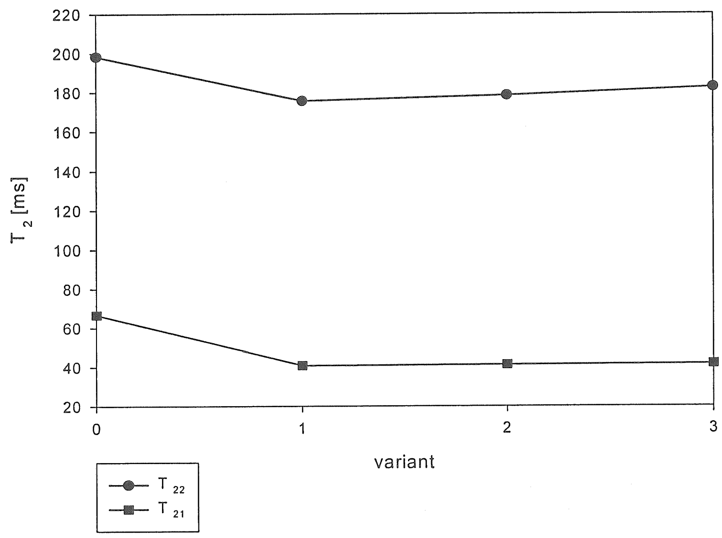

Fig.3. Changes in the values of spin-spin relaxation times in forcemeat

CONCLUSIONS

1. An analysis of the values of the indices investigated showed a diverse effect on the macro- and microstructure of the forcemeat when substituting fat with a pea cellulose preparation.
2. The substitution of 10% fat with a pea cellulose preparation is sufficient for the strong binding of water and the creation of a stable structure within the forcemeat.
3. An increase in the substitution of fat with pea cellulose of over 10% results in a decrease in viscosity and an increase in the dynamics of free water.

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OCENA WPŁYWU ZASTĄPIENIA TŁUSZCZU PREPARATEM BŁONNIKA GROCHU NA STAN ZWIĄZANIA WODY W FARSZACH WĘDLIN DROBNO ROZDROBNIONYCH

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Streszczenie. Celem podjętych badań była analiza stanu związania wody w farszach wędlin modelowych drobno rozdrobnionych, wyprodukowanych ze zróżnicowaną wymianą tłuszczu uwodnionym błonnikiem grochu. Przeprowadzono pomiary lepkości pozornej i czasów relaksacji spin-sieć i spin-spin. Wynik uzyskany z pomiarów lepkości sugeruje, że w przypadku zastosowania błonnika grochu jako zamiennika tłuszczu nie powinno się przekraczać wymiany wynoszącej 10%. Wyniki uzyskane z pomiarów czasów relaksacji spin-spin T_2 wskazują, że w układzie znajdują się dwie frakcje wody: frakcja wody związanej i frakcja wody wolnej. Zamiana tłuszczu błonnikiem grochu powoduje oddziaływania emulsji tłuszczowej z włóknami błonnika, co pozwala na dobre związanie składników farszu. Zbyt duża wymiana tłuszczu prowadzi jednak do sytuacji, w której w farszu zaczynają przeważać oddziaływania wody z błonnikiem bez udziału emulsji tłuszczowej. Farsz charakteryzuje się wtedy mniejszą lepkością na skutek nadmiaru wody słabo związanej.

Słowa kluczowe: błonnik grochu, tłuszcz, farsz