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THE EFFECT OF THE MODE OF HYDRATION OF STARCH PREPARATION ON THE DYNAMICS OF WATER IN FORCEMEAT AND THE FINAL PRODUCT

Hanna Maria Baranowska[1]*, Włodzimierz Dolata*[2]*, Elżbieta Piotrowska*[2]*, Magdalena Mańczak*[2]

[1]Department of Physics, [2]Institute of Meat Technology, University of Agriculture
ul. Wojska Polskiego 38/42, 60-637 Poznań
e-mail: hmbar@au.poznan.pl

A b s t r a c t. The study was undertaken to check the effect of the form of the E1412 starch preparation used as a substitute for some of the fat in highly refined sausages on their quality on the basis of the macro- and microscopic parameters characterizing the state of water in forcemeat and final sausages. The parameters determined included: thermal drip, free water content, total water, spin-lattice T_1 and spin-spin T_2 relaxation times. The best quality products were obtained with the starch product used in the form of 20% water dispersion prepared 24 hours before the process of chopping.

Keywords: modified potato starch, commuted forcemeat, fat, low-field NMR

INTRODUCTION

Food producers and food technology analysts have been working for some time now on new technologies of food products having energy value reduced through a decreased content of fat. Their effort has been a response to increasing consumer demands concerning the quality and nutritive value of food products, including meat products. The main problem limiting the reduction of fat content in meat products is the role of fat in determining the texture and sensory value of meat products.

The properties of the final product depend also on the proportions and interactions between the main components of forcemeat. The most important are the interactions between proteins-water, proteins-fat, proteins-proteins, which are responsible for water maintenance, stabilisation of emulsion, rheological properties and texture of the product. Therefore, the fat substitutes should meet specific requirements. In the meat products of lowered energy value, the fat should be replaced by a preparation which ensures desired physical, chemical and sensory properties. Most often, a part of fine fat is replaced by the same mass of hydrated substance [1,8,9], which leads to an increase in the water content above the recipe demands. Analysis of the macro-and microscopic parameters describing the state of water in forcemeat of lowered content of fat should always be made taking into account the increased water content.

The aim of the study reported was to analyse the effect of the form (mode of preparation) of the starch preparation E1412 used to replace part of the fat on the macro- and microscopic parameters describing the state of water in forcemeat and the final product. The ingredients of the forcemeat were modified in order to avoid the addition of water for hydration of the starch preparation. The starch preparation was introduced in three forms: without preliminary hydration (dry mass), 20% starch suspension and 20% starch gel.

MATERIAL AND METHODS

The experimental material consisted of model forcemeat, in which some of the fat had been substituted with a potato starch preparation. The forcemeat ingredients are listed in Table 1. In order to conform to the standard content of starch in the forcemeat [5], only 3% of the fat was replaced by starch preparation E1412 [5].

In variant 1 the starch preparation was introduced without preliminary hydration directly in the process of chopping, which is the most often used procedure. In variant 2 the starch preparation was introduced as a 20% starch gel prepared 24 hours prior to chopping and in variant 3 the starch preparation was introduced as a 20% suspension prepared 24 hours prior to chopping.

Table 1. Ingredients of forcemeat for refined sausages (g $(100g)^{-1}$)

Ingredient	Control	Variant 1	Variant 2	Variant 3
Pork meat, class III	48.71	48.71	48.71	48.71
Fine fat	20.88	17.88	17.88	17.88
Water	27.83	27.83	27.83	27.83
Additions (spices, NaCl)	2.58	2.58	2.58	2.58
Starch preparation E 1412	0.00	3.00	3.00	3.00

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

$$\%W_w = (a - b) \cdot 1.766 \quad (1)$$

where: *a* and *b* are the area of the drip and forcemeat respectively, 1.766 is a coefficient.

The content of total water in the final product was determined by drying and calculated from the formula:

$$Z_W = \frac{a-b}{c} \cdot 100\% \tag{2}$$

where: *a* and *b* are the masses of a given portion of forcemeat with blotting paper prior to and after drying, *c* is the mass of a weighed portion.

The thermal drip was determined by heating at 70°C for 30 minutes a certain mass (30 g) of forcemeat in a tube. Then the volume of the liquid forced out of the forcemeat in the thermal treatment was measured [11].

The spin-lattice T_1 and spin-spin T_2 relaxation times were measured in raw forcemeat, in forcemeat samples heated to +72°C for 25 minutes, and in the final product. These parameters describe the relations between the free and bound water and the dynamics of water molecules in the systems studied. The relaxation measurements were performed for raw forcemeat samples. After the measurements, the samples placed in closed measuring tubes were kept at +72°C for 25 minutes. The measurements were repeated for all samples in 24 hours after the heating. The relaxation times were also measured in the final product.

The measurements were performed on a pulse NMR spectrometer working at 30 MHz. Relaxation times T_1 were measured by using the inversion-recovery pulse sequence [10], the distance between the RF pulses (τ) was changed from 1 to 2000 ms, and the repetition time *TR* was 6 s. During each measurement 32 *FID* signals were recorded. The number of points in the signal amounted from 80 to 110. In the T_1 measurements 5 accumulations of signals were applied. Measurements of T_2 were made using a sequence of *CPMG* pulses [6, 12], with the distance between the pulses *TE* of 1 ms for raw forcemeat samples and 2 ms for the thermally treated forcemeat and the final product. In these measurements 12 accumulations were made.

The value of T_1 was 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 instantaneous values of magnetisation.

The values of the spin-lattice relaxation times were determined with the help of the program CracSpin [14]. Only one value of the relaxation time was found for all the samples.

The spin-spin relaxations times were obtained as a result of the fit with the formula [4]:

$$M_{x,y} = M_0 \sum_{i=1}^{n} p_i \exp\left(\frac{-TE}{T_{2i}}\right) \quad (4)$$

where: M_{xy} and M_0 are the actual and equilibrium values of spin echo amplitudes, p_i is the fraction of protons relaxing with the time T_{2i}

In all the samples studied, two fractions of protons were detected relaxing with two different T_2 times.

RESULTS AND DISCUSSION

The macroscopic parameters describing the state of water in the samples studied are given in Table 2.

Table 2. The content of free water and total water as well as thermal drip in the forcemeat

Parameter (%)	Control	Variant 1	Variant 2	Variant 3
Free water	6.10	7.04	6.51	7.01
Total water	62.4	63.86	63.03	63.41
Thermal drip	1.37	0.00	1.84	0.00

The content of free water and total water did not change significantly for all the variants of the starch product introduction, which confirms the validity of the assumption of unchanged water content in the system. Despite the preliminary hydration or gelation of the starch product, the amount of water in the system does not change.

Analysis of the thermal drip does not give unambiguous results. The result for the control sample is in agreement with data reported earlier **[7].** For the starch product introduced in the form of dry mass (variant 1) and as preliminary hydrated suspension, no thermal drip was detected. This observation means that in the process of thermal treatment of the forcemeat samples with 3% fat replaced by the starch product, water is fully bound at the sorption sites of denatured proteins and is involved in the process of starch gelation. When the starch product is introduced in the form of gel, the thermal drip is greater than that for the control sample, which is related to the process of retrogradation taking place in the system with gel. The lower amount of fat (containing proteins) relative to the control sample means that water is weaker bound with the protein matrix.

The use of NMR permits assessment of the state of the water bonding on the microscopic scale and analysis of its dynamic properties. The relaxation time T_1 describes interrelations between the free and bound water in the system.

The greater the amount of free water the longer the relaxation time. The only one value of T_1 time refers to the free water. The relaxation time T_2 describes the dynamic state of water. The two values obtained indicate the presence of two fractions of protons belonging to free and bound water.

Usually two values of the relaxation times T_2 are recorded for biological tissues or related systems [2,3]

The values of the spin-lattice times for the samples with the starch preparation introduced in the three forms into raw forcemeat, thermally treated forcemeat and final product are given in Figure 1.

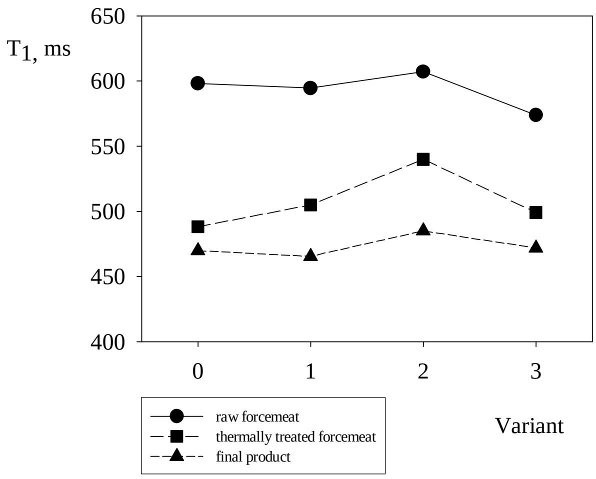

Fig. 1. The T_1 values for the samples with the starch preparation introduced in the three forms into raw forcemeat, thermally treated forcemeat and final product

The longest spin-lattice relaxation times were recorded for the raw forcemeat, which means that those samples contained the greatest amount of free water. The decrease in T_1 for the thermally treated forcemeat and for the final products proves that as a result of the thermal treatment water is bound in the system. Analysis of the results for the particular variants shows that for variant 2 the T_1 times are the longest for all kinds of samples. This means that the systems with starch preparation added in the form of gel contains the greatest amount of free water. Lower T_1 values relative to that for the control sample are those observed in variant 3. In those samples the water is the most strongly bound to the forcemeat components. It can be concluded that the best quality of the final product is obtained for the starch preparation added to forcemeat after preliminary hydration.

The dynamic state of the free and bound water in the system is described by the spin-spin relaxation time T_2. Figures 2 and 3 present the values of T_{21} – the short component referring to the bound water and the values of T_{22} – the longer component referring to the free water.

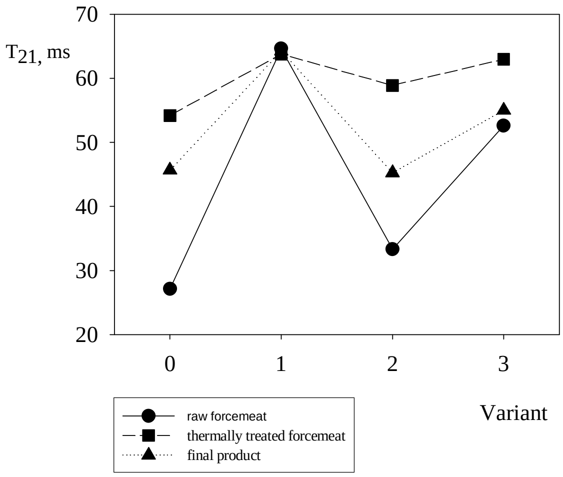

Fig. 2. Short component of the spin-spin relaxation time T_{21} for the three variants of the starch product introduction to raw forcemeat, thermally treated forcemeat and the final product

The values of T_{21} and T_{22} were always the lowest for the raw forcemeat and the highest for the thermally treated forcemeat.

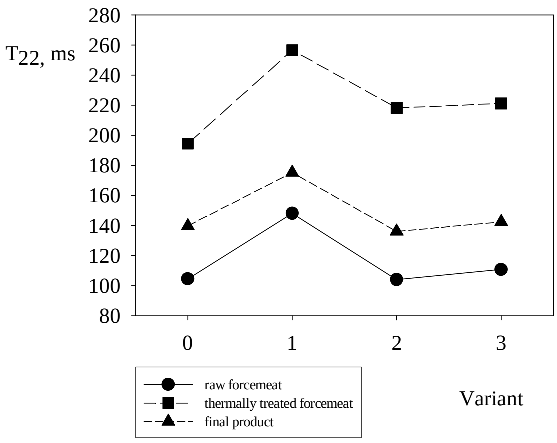

Fig. 3. Long component of the spin-spin relaxation time T_{22} for the three variants of the starch product introduction to raw forcemeat, thermally treated forcemeat and the final product

The short component T_{21} reaches the lowest values for the control sample (without the starch product) in the raw forcemeat, thermally treated forcemeat and in the final product. Addition of the starch product causes an increase in T_{21}. The addition of the starch preparation without preliminary hydration causes the greatest increase in this relaxation time component. The value of T_{21} obtained for the raw forcemeat in variant 1 is over twice greater than in the control sample. In forcemeat as well in the final product the water molecules are mobile. This conclusion is confirmed by the results obtained for long component of spin-spin relaxation time. For this variant of the experiment, the T_{22} values are the longest. The strongest bound water – the lowest dynamics of the water molecules – ($T_{2ł}$ values) was obtained for the variant in which the starch product was introduced in the gel form. Also, the T_{22} values were the lowest in this variant. It suggests that no matter whether starch, starch products or modified starch are introduced, the most important role for water state of the final product is played by the interactions between the water molecules and the polymer.

Analysis of the NMR results obtained has indicated that both the degree of hydration and the molecular dynamics of water are characterised by the best parameters describing the microscopic state of water for the variant in which the fat replacing starch product is introduced in the form of suspension. The results have also suggested that the introduction of the starch product to forcemeat without its preliminary hydration causes undesirable interactions between the free and bound water in the system.

CONCLUSIONS

1. The replacement of up to 3% of fat mass by the same mass of the starch preparation guarantees positive bonding of water both in forcemeat and in the final product.

2. Starch or starch products used as a fat substitute should be preliminary hydrated. This procedure strengthens the water bonding in the forcemeat and in the final product.

3. The addition of starch product as a fat substitute to chopped forcemeat without preliminary hydration is not effective. In such systems the water is weakly bound and shows mobility much higher than for any other variants.

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WPŁYW SPOSOBU UWODNIENIA PREPARATU SKROBIOWEGO NA STAN DYNAMICZNY WODY W FARSZU WĘDLIN DROBNO ROZDROBNIONYCH I GOTOWYM WYROBIE

Hanna Maria Baranowska[1], Włodzimierz Dolata[2], Elżbieta Piotrowska[2], Magdalena Mańczak[2]

[1]Katedra Fizyki, [2]Instytut Technologii Mięsa, Akademia Rolnicza
ul. Wojska Polskiego 38/42, 60-637 Poznań
e-mail: hmbar@au.poznan.pl

Streszczenie. W pracy podjęto badania dotyczące wpływu sposobu przygotowania preparatu skrobiowego E 1412 zastępującego część tłuszczu w wędlinach drobno rozdrobnionych na ich jakość. Badano makro i mikroskopowe parametry charakteryzujące stan wody w farszach i w wyprodukowanych wędlinach. Oznaczono następujące parametry: ilość wycieku cieplnego, zawartość wody wolnej, całkowitą zawartość wody, czasy relaksacji spin-sieć T_1 i spin-spin T_2. Przeprowadzone badania wykazały, że najskuteczniejszą formą przygotowania preparatu skrobiowego jest jego 20% dyspersja wodna, przygotowana 24 godziny przed rozpoczęciem procesu kutrowania.

Słowa kluczowe: modyfikowana skrobia ziemniaczana, farsz drobno rozdrobniony, tłuszcz, NMR