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HANNA MARIA BARANOWSKA[1], ELŻBIETA PIOTROWSKA[2], RYSZARD REZLER[1], WŁODZIMIERZ DOLATA[2]

[1]Department of Physics
[2]Institute of Meat Technology
August Cieszkowski Agricultural University of Poznań

ANALYSIS OF THE PROPERTIES OF MEAT BATTER WITH FAT REPLACED OF WHEAT AND OAT FIBER

Summary. The state of water in meat batter modified with wheat and oat fibre was investigated by the method of low field nuclear magnetic resonance (NMR). The study was performed for meat batter of model meat products. The fat was replaced by wheat fiber (Vitacel WF 200) or oat fiber (Vitacel HF 200) in the amounts of 5%, 7.5%, 10%. The fiber was mixed with water at the ratio 1:5. The modified products were subjected to measurements of free water content, apparent viscosity, spin-lattice R_1 and spin-spin R_2 relaxation rates. All the samples modified with wheat and oat fibres showed greater free water content than the control sample. The apparent viscosity of all samples of meat batter modified with natural fiber was found to decrease with increasing fiber content. Significant differences between the R_1 values for the control sample and all the samples modified with fiber mean that water is weakly bonded in the system. For the samples modified with oat fiber the relaxation rate R_1 increased with increasing fiber content, which suggests a decrease in the free water content in these systems. The values of the relaxation rate R_2 brings information on the mobility of free water molecules in the samples as its value decreases with increasing water mobility. The changes in the water mobility of modified samples were irregular. Analysis of the parameters R_1 and R_2 indicates that the fat substitution of 7.5% of fiber is the best. The increase in R_1 for the modified samples with respect to the value for unmodified sample suggests a decrease in the free water content in the former, which means that the water is well bonded with the meat batter components, and in particular with the fiber added.

Key words: wheat and oat fiber, meat batter, relaxation rates, free water

Introduction

Finely comminuted sausages are common food products so their quality and nutrition value are of great concern. Recently much attention has been paid to enrich such food products in functional additives of natural origin, which could partly replace animal fat (DOLATA et AL. 2002). Such modified food products should be characterised not only by improved taste and nutrition properties but should also have desired physico-chemical properties. In this aspect the state of water in meat batter supplemented with natural cellulose preparations is of particular importance.

In this study the state of water in meat batter modified with natural cellulose was investigated by the method of Nuclear Magnetic Resonance (NMR) mainly because this technique is non-invasive and non-destructive (BERTRAM et AL. 2004 a, b, LAURENT et AL. 2000, SORLAND et AL. 2004). Results of the measurements of the spin-lattice and spin-spin relaxation rate bring information on the state of water bonding in meat batter (BERTRAM et AL. 2001, 2002, BARANOWSKA et AL. 2004 a, b, 2003, PIOTROWSKA et AL. 2004). The rate of spin-lattice relaxation decreases with increasing content of free water in the preparation studied. Moreover, the measurements of spin-spin relaxation rate provide information on the water molecules mobility.

Materials and methods

The study was performed for meat batter of model meat products. According to the recipe the forcemeat contained: 3rd class pork (48%), fine fat (20.8%), water (29%) and preserving salt (2.2%). The fat was replaced by wheat fiber (Vitacel WF 200) or oat fiber (Vitacel HF 200) in the amounts of 5%, 7.5%, 10%. The fiber was mixed with water at the ratio 1:5. The modified products were subjected to measurements of free water content, apparent viscosity, spin-lattice and spin-spin relaxation rates.

Free water content was measured by the Volowińska and Kelman method (BARANOWSKA et AL. 2004 b). A 0.3 g sample of the meat batter (weighted to the accuracy of 0.0001 g) was placed on a tissue, covered with foil and pressed with a load of 1 kg for 20 min. Then, the size of the meat batter mark and the size of the water leak mark were measured by a planimeter.

The content of free water was calculated according to the formula:

$$W_w = (a \cdot b) \cdot 1.766 \cdot 100\% \tag{1}$$

where:

a – the area of the water leak mark (cm^2),
b – the area of the forcemeat mark (cm^2),
1.766 – the calculation coefficient.

The meat batter viscosity was measured by a reoviscometer VT 550 made by Haake. The measurements were made at the shear rate of 1.0 s^{-1}. The result was read out for the maximum value of the rotation angle α. The apparent viscosity η was found from the formula (BARANOWSKA et AL. 2004 b]:

$$\eta = (a \cdot z)/\gamma \tag{2}$$

where:

α – the angle of rotation (Skt),
z – a cylinder constant,
z = 86 ($Nm^{-2}Skt^{-1}$),
γ – the shear rate (s^{-1}).

The measurements of spin-lattice relaxation times $T_1(=1/R_1)$ and spin-spin relaxation times $T_2(=1/R_2)$ were performed on a pulse NMR spectrometer working at the frequency 30 MHz. The spin-lattice relaxation time (T_1) was measured applying the inversion-recovery pulse sequence (π–τ–$\pi/2$; FUKUSHIMA and ROEDER 1981). The distance between pulses (τ), was changed from 0.5 to 1000 ms, depending on the sample. Accumulation of 30 free induction decay (FID) signals was made and each FID signal included 100 points. The repetition time for each measurement was TR 10 s. The measurement temperature was 20 ± 1°C. For samples of different water content from 4 to 8 accumulations were made, depending on the sample. The values of T_1 were calculated from equation (3) using the CracSpin program (WĘGLARZ and HARAŃCZYK 2000):

$$M_z(TI) = M_0(1 - 2\exp(-TI/T_1)) \tag{3}$$

where:

M_0, $M_z(TI)$ – the equilibrium and current values of magnetisation, respectively,
TI – distance between pulses.

The spin-spin relaxation time T_2 was measured using the CPMG pulse sequence (CARR and PURCELL 1954, MEIBOOM and GILL 1958). The values of T_2 were obtained from the fit of the spin echoes amplitude to the formula:

$$M_{x,y} = M_0 \exp(-TE/T_2) \tag{4}$$

where:

$M_{x,y}$ – the spin echo amplitude,
TE – the distance between pulses.

During each measurement the amplitudes of 50 spin-echo signals were accumulated. The values of TE varied from 1 to 3 ms, depending on the sample. In the paper only the values of the spin-spin relaxation rates for free water are presented. The experiments were performed for three production series. Five samples were collected from each series. The variance analysis was applied for the obtained results. The analysis was made at the significance level $p < 0.05$.

Results and discussion

The values of the free water determined for the meat batter samples containing 5%, 7.5% and 10% of hydrated wheat or oat fibre were compared with the corresponding data obtained for the control sample without modification. The mean values of five measurements of each of these parameters are given in Table 1.

All the samples modified with wheat fiber showed greater free water content than the control sample. For the sample with 7.5% addition of hydration wheat fiber the difference in free water content from that in the control sample was the smallest. The samples modified with hydrated oat fiber were also characterised by higher free water content than the control sample, and the values of this parameter increased with the increasing oat fiber concentration.

Table 1. Mean values of free water content in meat batter modified with wheat and oat fiber
Tabela 1. Średnie wartości zawartości wody wolnej w farszach modyfikowanych błonnikiem pszennym i owsianym

Fiber	The replacement of fat with fiber (%)			
	0	5	7.5	10
Wheat	11.93^{a}	15.97^{b}	14.62^{c}	15.97^{b}
Oat	11.93^{a}	15.97^{b}	16.23^{d}	16.30^{d}

a, b, c, d – mean with different letter in rows differ significantly statistically at $p < 0.05$.

The viscosity of all samples of meat batter modified with fibers was found to decrease with increasing hydrated fiber content (Fig. 1). The least differences in viscosity from the value for the control sample were observed for the samples with 5% hydrated fibre content. For the samples modified with oat fiber the apparent viscosity decreased linearly with increasing content of the hydrated fiber. The decrease of the viscosity was interpreted as related to the increasing amount of water introduced to these samples.

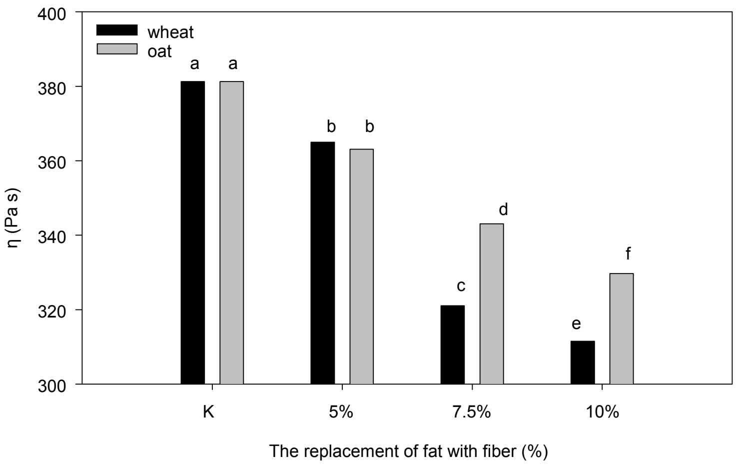

Fig. 1. Mean values of the viscosity in meat batter modified with hydrated wheat and oat fiber
Rys. 1. Średnie wartości lepkości pozornej w farszach modyfikowanych uwodnionym błonnikiem pszennym i owsianym

In Figure 2 are presented the values of the mean spin-lattice relaxation rates in the investigated systems. The relaxation rate R_1 decreased with increasing amount of the content of wheat fiber, which suggests an increase of free water content in these systems. Significant differences between the R_1 values for the control sample and all the samples modified with fibre mean that water is weakly bonded in all samples. For the samples modified with hydrated oat fiber the relaxation rate R_1 increased with increasing fibre content, which suggests a decrease in the free water content in these systems.

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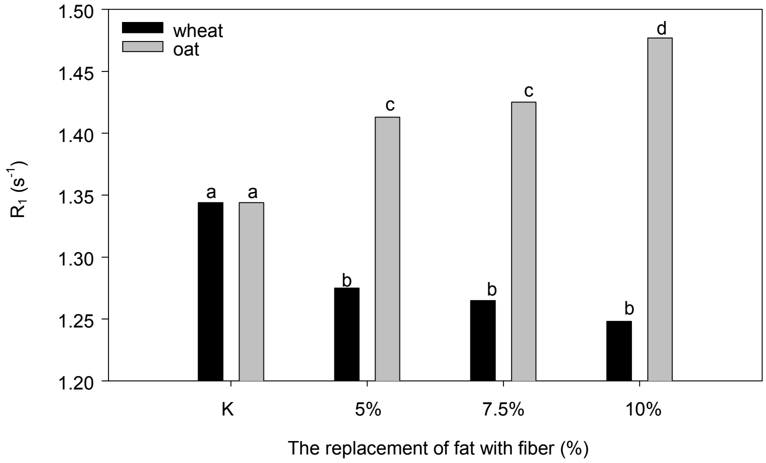

Fig. 2. Mean values of the spin-lattice relaxation rates R_1 in meat batter modified with hydrated wheat and oat fiber
Rys. 2. Średnie wartości szybkości relaksacji spin-sieć R_1 w farszach modyfikowanych uwodnionym błonnikiem pszennym i owsianym

The values of the relaxation rate R_2 brings information on the mobility of water molecules in the samples as its value decreases with increasing water mobility. The changes in the fraction of the free water mobility of modified samples were irregular (Fig. 3).

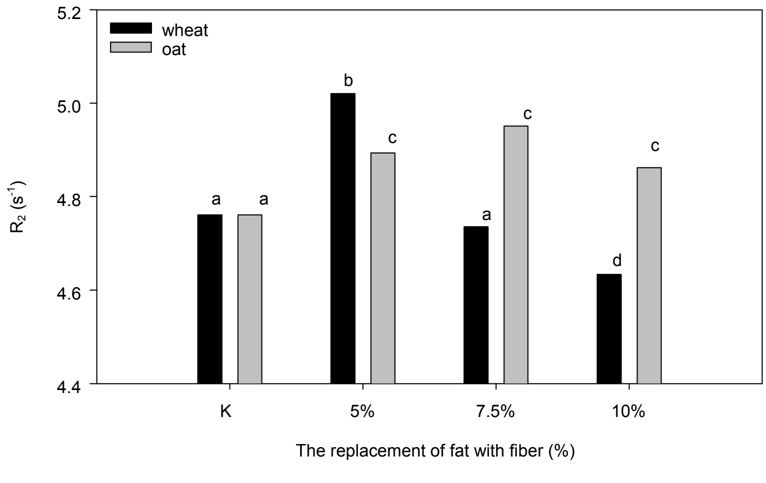

Fig. 3. Mean values of the spin-spin relaxation rates R_2 in meat batter modified with hydrated wheat and oat fiber
Rys. 3. Średnie wartości szybkości relaksacji spin-spin R_2 w farszach modyfikowanych uwodnionym błonnikiem pszennym i owsianym

In the sample with a 5% addition of hydrated wheat fiber the water was the least mobility when compared to that in the control sample. In the sample with 7.5% hydrated fiber addition the R_2 was the same as in the control sample. In the sample with 10% hydrated fiber addition water mobility was a little greater than in the sample with 7.5% fiber content. For the samples with hydrated oat fiber additions the changes in R_2 were irregular. The water molecules was less mobility than in control in these samples.

Analysis of all the parameters measured indicates that the 10% hydrated fiber addition is too high because of significant differences in their values when compared to the unmodified sample. The values describing the mobility of free water molecules in the sample with 7.5% hydrated fiber addition and the control sample are comparable. A significant decrease in the viscosity of forcemeat with hydrated wheat fiber should be connected with an increasing amount of free water in the modified samples, which is confirmed by the values of R_1. Although the values of viscosity were significantly different for the samples with 5% and 7.5% hydrated fiber addition, the values of R_1 for these two samples did not differ much. This result can suggest that the sample with 7.5% hydrated fiber addition contains free water but it is as well bonded with the meat batter component as in the sample with 5% of hydrated fiber.

In general, analysis of the parameters R_1 and R_2 indicates that the addition of 7.5% of hydrated fiber is the best. The increase in R_1 for the modified samples with respect to the value for unmodified sample suggests a decrease in the free water content in the former, which means that the water is well bonded with the forcemeat components, and in particular with the fiber added.

The parameters characterising meat batter samples in which fat has been replaced with wheat fiber in the amount of 5%, 7.5%, 10% indicate great water absorption ability of this polymer. On absorbing water the fiber forms a certain structure in the meat batter. High decrease in apparent viscosity of the samples containing 7.5% and 10% hydrated fiber additions suggest that the fiber is poorly bonded with the other meat batter components forming a separate network destroyed on the mechanical measurements of apparent viscosity. The amount of free water increases with increasing amount of hydrated fiber addition. In the sample containing 7.5% of hydrated fiber the water mobility is comparable with that in the control sample. Thus, it seems that from this point of view the hydrated fiber addition of 7.5% seems the best of all considered.

The apparent viscosity and the parameters describing the dynamics of water absorption and bonding change in proportion to the amount of the hydrated fiber added. The water mobility decreases with the amount of fiber added, which means that oat fiber is a good water absorber and is well bonded with the other components of meat batter.

Conclusions

1. The addition of wheat fiber to meat batter causes significant decrease of free water content measured with classic methods as compared to oat fiber.

2. Meat batter with wheat fiber addition is characterized by a much lower apparent viscosity as compared to systems including oat fiber.

3. The wheat fiber hydrated in proportion 1:5 added to meat batter is a good water absorber and forms there structures containing certain amounts of water restricted to the total meat batter structure.

4. The properties of the samples containing oat fiber hydrated in proportion 1:5 as fat replacement in meat batter indicate that the water is well bonded.

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ANALIZA WŁAŚCIWOŚCI FARSZÓW DROBNO ROZDROBNIONYCH Z UDZIAŁEM BŁONNIKÓW PSZENNEGO I OWSIANEGO

Streszczenie. W pracy przedstawiono wyniki badań nad stanem związania wody w farszach z dodatkiem błonnika pszennego i błonnika owsianego z wykorzystaniem techniki magnetycznego rezonansu jądrowego. Analizowano farsze modelowe, w których 5, 7,5 i 10% tłuszczu wymieniano uwodnionym w stosunku 1:5 błonnikiem pszennym Vitacel WF 200 i błonnikiem owsianym Vitacel HF 200. Analizowano zmiany zawartości wody wolnej, lepkości i szybkości relaksacji spin-sieć R_1 i spin-spin R_2 wody wolnej. Wszystkie układy zawierające błonniki charakteryzowały się wzrostem zawartości wody wolnej oraz spadkiem lepkości. Wyniki pomiarów szybkości relaksacji pozwalają na analizę stanu związania wody w układzie. Szybkości relaksacji spin--sieć maleją ze wzrostem zawartości błonnika pszennego, co sugeruje zwiększenie zawartości wody wolnej w układzie. Różnice pomiędzy wartościami R_1 dla próby kontrolnej i wszystkich prób modyfikowanych tym błonnikiem oznaczają, że woda jest słabo wiązana w układzie. W wypadku zastosowania błonnika owsianego wartości R_1 wzrastają ze zwiększeniem zawartości błonnika w układzie, co należy interpretować jako spadek zawartości wody wolnej. Wartości szybkości relaksacji spin-spin R_2 odzwierciedlają ruchliwość molekuł frakcji wody wolnej. Zmiany tego parametru są nieregularne. Analiza parametrów relaksacyjnych wskazuje, że optymalna wydaje się wymiana tłuszczu w ilości 7,5%. Wzrost wartości R_1 w próbach z dodatkiem błonnika w porównaniu z kontrolą sugeruje zmniejszenie zawartości wody wolnej. Oznacza to, że woda jest dobrze wiązana ze składnikami farszu i dodanym błonnikiem.

Słowa kluczowe: błonniki pszenny i owsiany, farsz drobno rozdrobniony, szybkości relaksacji, woda wolna

Corresponding address – Adres do korespondencji:
Hanna Maria Baranowska, Katedra Fizyki, Akademia Rolnicza im. Augusta Cieszkowskiego, Wojska Polskiego 38/42, 60-637 Poznań, Poland, e-mail: hmbar@au.poznan.pl

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