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Magnetic resonance imaging method of rapid remote control of casein concentration in milk products in unopened packages

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We propose a new nuclear magnetic resonance (NMR) method of rapid remote determination of casein concentration in dairy products in unopened packages. The method was successfully tested for whole milk products in unopened packages. The milk products had a fat concentration in a range of 0–6 %, casein concentration in a range of 0–3 % and were produced by different manufacturers of Leningrad Region, Russia. Because of the milk packages had different sizes and shapes we used a new receiver MRI solenoid which has a variable radius and shape for an improvement of signal to noise ratio of MR images of milk products measured in MR imaging system, GEMS Vectra, 0.5 T [1].

Keywords: method of the nucleus magnetic resonance, concentration of casein, milk products

Магнитный резонанс как метод дистанционного контроля концентрации казеина в молочных продуктах в закрытых пакетах

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В работе предложен новый метод ядерного магнитного резонанса (NMR) для быстрого дистанционного определения концентрации казеина в молочных продуктах в закрытых пакетах. Метод успешно был протестирован для цельных молочных продуктов в закрытых пакетах. Молочные продукты имели концентрацию жира в диапазоне 0-6 %, концентрация казеина в диапазоне 0-3 %, те же самые испытания были произведены для других изготовителей Ленинградской области.

Ключевые слова: метод ядерного магнитного резонанса, концентрация казеина, молочные продукты

In a recent work it was shown the water proton spin-spin relaxation time (T_2) of model mixtures containing of native phosphocaseinate, whey protein and lactose depends on the casein concentration [2]. According to the authors knowledge the analogous research was not presented in literature for whole commercial milk samples having different fat and casein concentrations, of different manufacturers and for milk samples in unopened packages. The paper presents these results obtained

via MRI relaxometry (GEMS Vectra 0.5 T MR imaging system) of whole commercial milk samples in unopened packages (fig. 1).

The investigations showed the T_2 time of water protons in milk samples with a fat concentration of 0–3.2 % and of four manufacturers from Leningrad Region, Russia does not depend on the fat concentration and the manufacturers within the accuracy of the measurements, see figures 3 and 4.

We conducted the measurements of T_2 of water protons in milk samples in unopened packages for different casein concentrations. The figures 2–4 show the MR images and T_2 relaxometry data. The casein concentrations in milk "Lateo" with 2.5 % of fat (Kingisepp milk factory, Russia) and in a pasteurized whey (Lactis Ltd., Russia) were 3 and 0 % respectively. The two other milk samples with different casein concentrations were obtained by a dilution method. We chose a filtered tap water for the dilution. The water has the T_2 time nearly equal to the one of the whey, Lactis Ltd. We diluted the milk "LATEO" with 2.5 % of fat by the water. The measured dependence of the water proton relaxation rate $1/T_2$ of the samples on the casein concentration is given in figure 5. The experimental points are approximated by a straight line. In table 1 we compared the linear regression slope in figure 5 with the slope obtained for model mixtures containing native phosphocaseinate, whey proteins and lactose [2]. These values are the same within the experimental accuracy. On the basis of the conducted investigations we conclude the water proton relaxation rate $1/T_2$ of whole commercial milk samples of different fat and casein concentrations and of different manufacturers of Leningrad Region, Russia depend on the casein concentration.

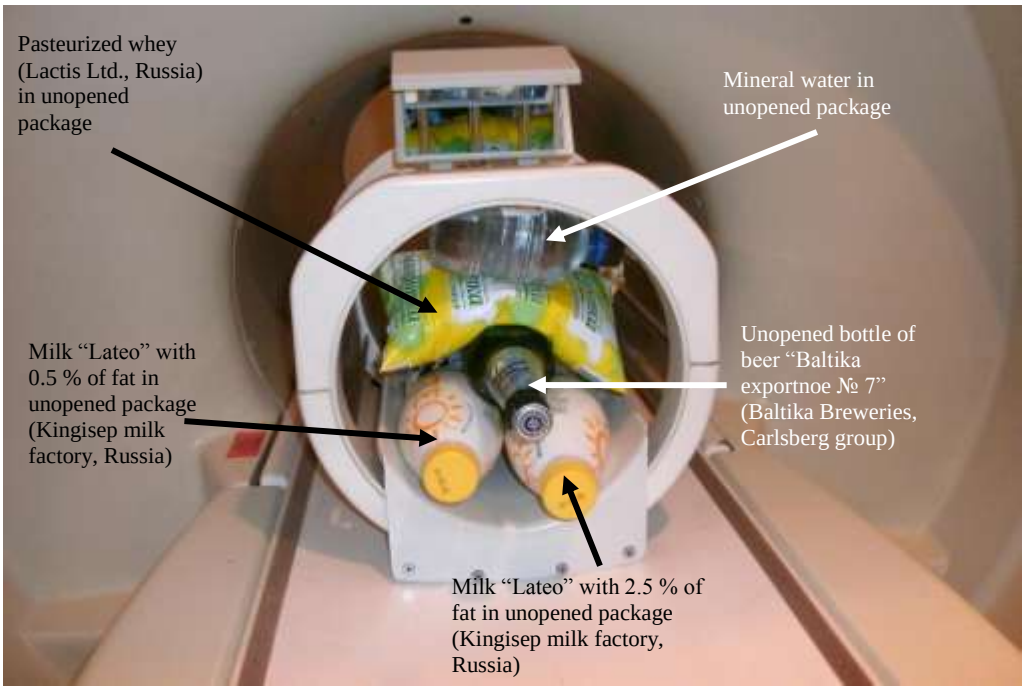

Fig. 1. Food products are placed inside MR imaging system for a quality control

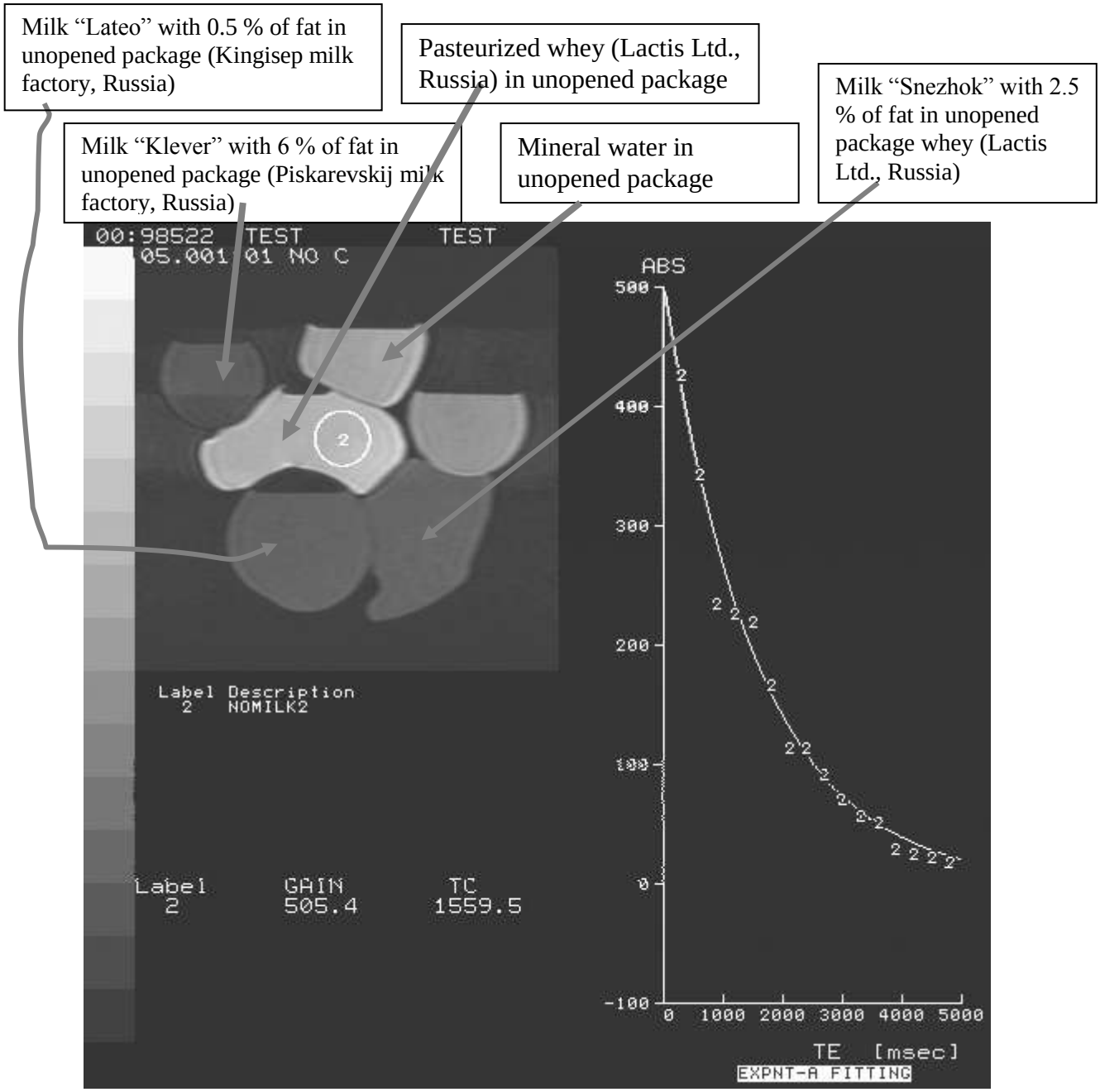

Fig. 2. Simultaneous quality control of all set of dairy products. The plot on the right is the water proton T_2 relaxation curve in the pasteurized whey (Lactis Ltd., Russia) in unopened package. The casein concentration of the whey is equal to zero

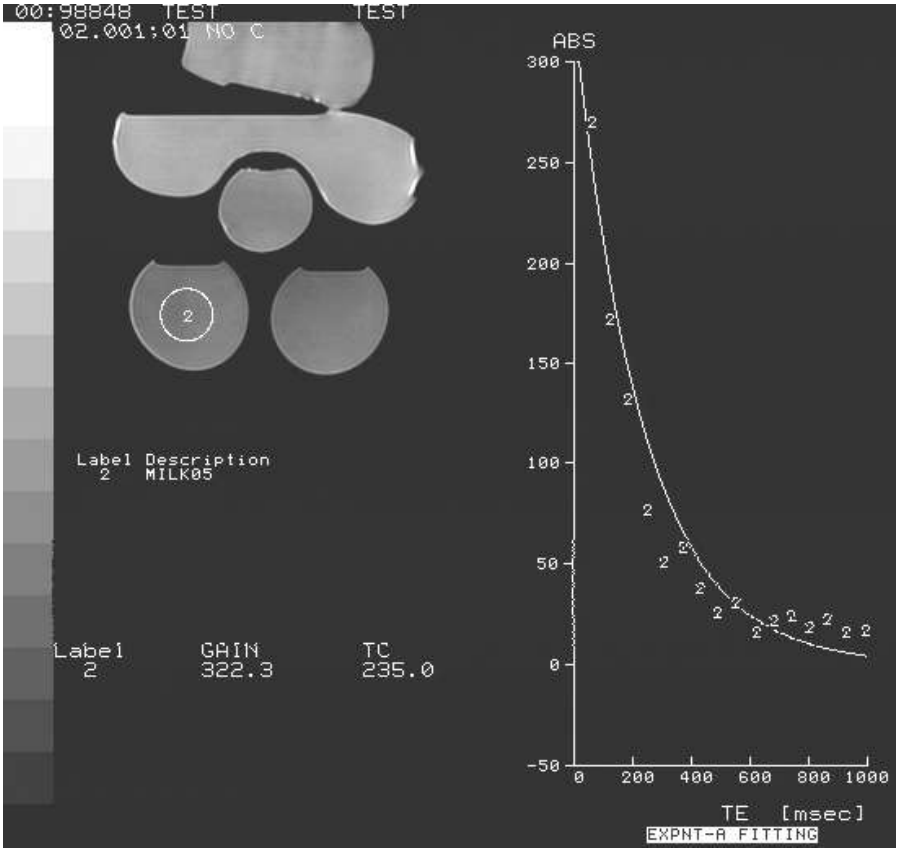

Fig. 3. Simultaneous quality control of all set of food products. These products are the same as in Fig. 3. The plot on the right is water proton T_2 relaxation curve in milk «LATEO» with 0.5 % of fat in unopened package. These food products are presented in Fig. 1.

Table 1. Comparison of the linear regression date of fig. 5 with the data obtained for model mixtures of casein, whey protein and lactose

Reference	**Slope**	**Correlation coefficient**	**pH**
This work	116 $\pm$ 28	0.96	6.51
[3]	152.2 $\pm$ 1.1	0.999	6.6

We showed the water proton relaxation rate $1/T_2$ of whole commercial milk samples of different fat and casein concentrations and of different milk manufacturers of Leningrad Region, Russia is a linear function of casein concentration and do not depend on fat concentrations and the

manufacturers. These results are the basis for a new NMR method of the casein concentration determination which can have the following applications.

1. Rapid remote detection of an adulteration of casein concentration in dairy products, particularly in unopened packages. They could be milk, condensed milk, curds produced with the use of adulterated skim milk powder containing whey powder [3]. According to a preliminary estimate a minimal casein concentration detected by the proposed method is less than 0.5 %.
2. This method in conjunction with MR imaging can be applied for a remote investigation of spatial distribution of hydration parameters (hydration amount, water mobility in hydration shells) of casein micelles during production processes, storage and quality control of dairy products in unopened packages.

Our experiments also showed that this method of ^{1}H MRI relaxometry is informative in an investigation of beer and meat products in unopened packages.

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