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EFFECT OF CONCENTRATED MICROWAVE FIELD ON THE REOLOGICAL PROPERTIES OF LIQUID WHOLE EGG

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Summary. Microwave treatment of egg products seems to be alternative way of traditional pasteurization. The influence of concentrated microwave field on rheological parameters of liquid whole egg was examined in the experiment. It was found that viscosity of liquid whole egg had increased after microwave treatment. Addition of higher level of vitamins or fat and Humokarbowit additives into feed for laying hens resulted in changing of LWE rheological parameters such as: viscosity η [mPa s], shear rate γ' [1/s], shear stress τ [Pa] and shear strain γ [-].

Keywords: liquid whole egg, microwave field, rheological properties, viscosity.

INTRODUCTION

Concentrated microwave field is one of the alternative ways of inactivating of pathogen microflora in food product. Microbiological studies are very important because of safety of food products, but also another investigations such as functional or rheological studies are significant for food technologist. There are numerous reasons that rheological data are needed in the food industry: process engineering calculations involving a wide range of equipment such as pipelines, pumps, extruders, mixers, coaters, heat exchangers, homogenizers, calenders, and on-line viscometers; determining ingredient functionality in product development; intermediate or final product quality control; shelf life testing; evaluation of food texture by correlation to sensory data; analysis of rheological constitutive equations [1,5,6]. Liquid whole egg (LWE) must be pasteurized or ultrapasturized at 64 - 68°C for suitable time (till 2.5 minute for 64.4°C) to inactivate pathogen microflora [3,8]. To increase the lethality of pasterization is not generally a viable proposition due to the physical properties of the LWE. An increase in temperature would lead to the formation of an egg protein gel during the holding stage of pasteurization. A short holding time increase would not significantly reduce the numbers of thermoduric organisms surviving pasteurization and a significant increase would not be economically feasible [3]. Another methods like concetrated microwave fields should be therefore investigate to maximize the shelf life of the product with the best possible preservation of its functional and rheological properties.

A general relationship to describe the behavior of non-Newtonian fluids is the Herschel-Bulkley model [2, 4, 9, 10]:

$$\tau = K(\dot{\gamma})^n + \tau_o$$

where: τ - shear stress [Pa],
K – consistency coefficient [Pa s^n],
γ – shear rate [s^{-1}],
n – flow behavior index,
τ_o - yield stress [Pa].

This model is appropriate for many fluid foods (Fig. 1) and very convenient because Newtonian, power law (shear-thinning when 0<n<1 or shear thickening when 1<n<∞) and Bingham plastic behavior may be considered as special cases. With the Newtonian and Bingham plastic models, K is commonly called the viscosity and plastic viscosity, respectively [10]. An important characteristics of the Herschel-Bulkley and Bingham plastic materials is presence of a yield stress which represents a finite stress required to achieve flow [7].

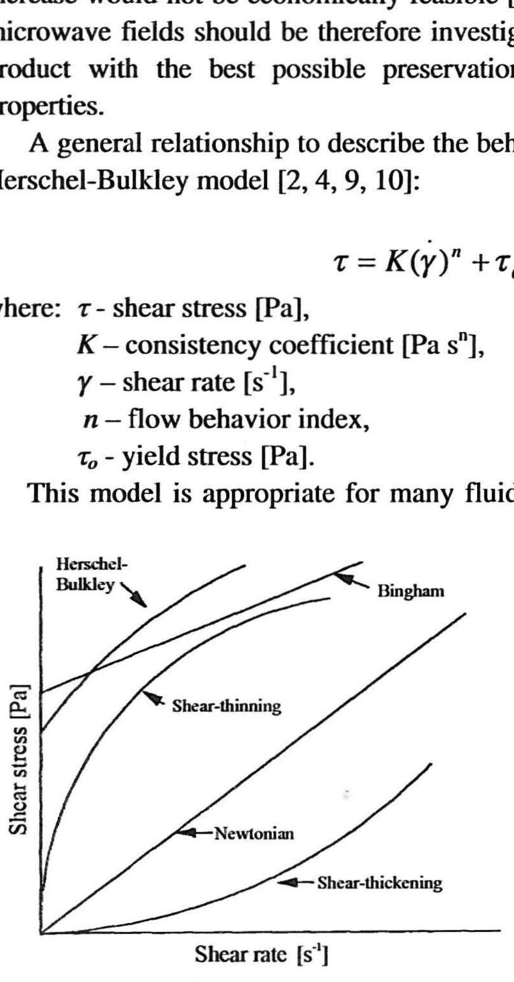

Fig. 1. Curves for typical time-independent fluids [10].

MATERIALS AND METHODS

Hy-Line hens aged 37 weeks used in experiment were assigned to 3 dietary treatment groups. Layers were fed: 1) classical feed without special additives; 2) standard feed (DJ) with higher level of fat and 2% of Humokarbowit; 3) standard feed (DJ) with higher level of vitamins (25%), minerals (Zn, Se, etc), fat and 2% of Humokarbowit additive obtained from Tronina Company. Collected eggs were stored in $T = 18^{\circ}C$ during 4 weeks to check their rheological properties after that time. Part of LWE was kept in $T = 4^{\circ}C$ during 48 hours after microwave treatment to investigate effect of cold storage on rheological parameters. It was 12 treatment groups used in experiment (3 dietary groups x 2 groups with or without microwave treatment x 2 groups with or without cold storage). Microwave treatment was conducted with use of "Microwave Reactor RM2001" produced by Plazmatronika Company, Wrocław, Poland. 0.15 litre of LWE was placed into reaction vessel and microwave treatment was carried out according to input temperature, time and power parameters. LWE reach maximum temperature of 65°C during 2 minutes. LWE both before and after microwave treatment was investigated in HAAKE RS 100 rheometer for rheological studies. Measurements were conducted in temperature 20°C and obtained results using HAAKE RheoWin Pro 2.6 software were plotted on diagrams: as relationship "Shear rate γ' [1/s] - Shear stress τ [Pa]", "Viscosity η [mPa s] - Shear stress τ [Pa]" or "Shear strain γ [-] - Shear stress τ [Pa]". Shear rate γ' [1/s] and shear strain γ [-] in function of shear stress τ [Pa] are shown in Fig. 2 as example of typical result chart.

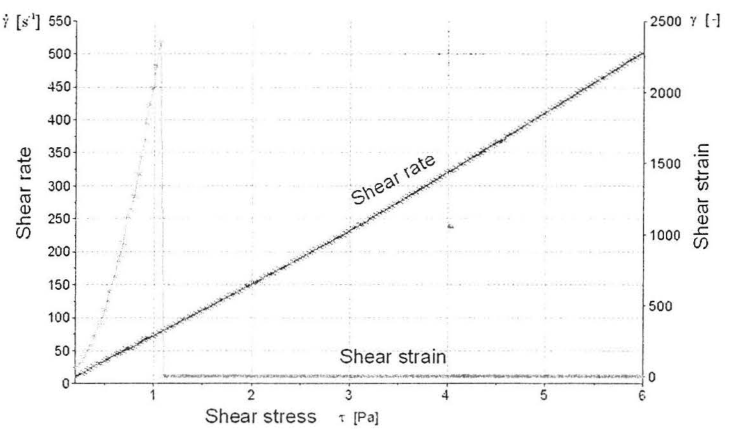

Fig. 2. Typical chart of shear rate γ' [s^{-1}] and shear strain γ [-] in function of shear stress τ [Pa] (product: liquid whole egg).

RESULTS AND DISCUSSION

One of equations describing rheological properties of fluids used in our experiment was as below:

$$\eta = a\tau + b$$

where: η - viscosity [Pa s],
τ - shear stress [Pa],
a, b – coefficients.

Above relationship was obtained according to regression equations determined for all experimental treatments. Regression coefficient R^2 was greater than 0.90 for all equations. Relationship $\eta = a\tau + b$ was fitted in all cases for range of shear stress 0.5-6.0 [Pa]. Coefficients "a" and "b" calculated from equations are presented in Table 1. All 12 treatments were characterised by negative values of "a" coefficient. It means that value of viscosity decreased along with increasing shear stress. The most intensive decrease of viscosity (a = -0.8286) was for LWE after microwave treatment where addition of higher level of vitamins (without keeping LWE 48 hours at $T = 4^{o}C$) was applied. Microwave treatment was main factor influencing on "a" value especially for raw material obtained from laying hens fed classical feed.

Coefficient "b", which can be considered as estimated viscosity (at $\tau = 0$), ranged from 8.49 to 28.04 (Table 1). Liquid whole egg after microwave treatment was characterised by higher "b" values (till 28.04) than before treatment (till 14.11).

Table 1. Values of "a" and "b" coefficients in equation $\eta = a\tau + b$ for liquid whole egg in dependence of experimental treatment

	Classical feed		Classical feed with addition of fat and Humokarbowit		Classical feed with addition of vitamins	
	No cold storage	48 hrs of cold storage	No cold storage	48 hrs of cold storage	No cold storage	48 hrs of cold storage
Before microwave treatment	a= -0.5174 ------- b = 10.36	a= -0.6864 ------- b = 12.90	a= -0.3909 ------- b = 14.11	a= -0.4186 ------- b = 13.62	a= -0.2326 ------- b = 8.49	a= -0.2901 ------- b = 11.71
After microwave treatment	a= -0.1290 ------- b = 23.29	a= -0.1539 ------- b = 28.04	a= -0.6327 ------- b = 24.64	a= -0.2457 ------- b = 27.42	a= -0.8286 ------- b = 13.99	a= -0.1578 ------- b = 19.86

Viscosity was also higher for LWE kept 48 hours at $T = 4^{o}C$ (cold storage) in comparision to LWE without cold storage. Effect of layers dietary treatment on "b" values was also observed: addition of higher level of vitamins resulted in decrease of LWE viscosity.

Curves of shear strain were helpful to determine values of shear stress [Pa] and shear rate [1/s]. A typical Newtonian behaviour of investigated fluids (LWE) appeared (Fig. 1). Obtained results are presented in Table 2. All shear rates were close to 80 [1/s], but shear stresses were very unique. In all cases shear stress was higher for LWE after microwave treatment (till 1.804 Pa) in comparision to LWE before microwave treatment (till 1.069 Pa). LWE kept 48 hours at $T = 4^{o}C$ before rheological measurements were characterised by higher values of shear stress compared to LWE without cold storage. The third factor influencing on results was dietary treatment. Addition of higher level of vitamin into feed resulted in lowering of LWE shear stress values.

Recent studies indicated that microwave treatment affected LWE characteristics and better understanding of rheological changes may help in obtaining better quality of final egg products.

Table 2. Values of shear stress [Pa] and shear rate [1/s] for liquid whole egg in dependence of experimental treatment

	Classical feed		Classical feed with addition of fat and Humokarbowit		Classical feed with addition of vitamins	
	No cold storage	48 hrs of cold storage	No cold storage	48 hrs of cold storage	No cold storage	48 hrs of cold storage
Before microwave treatment	0.800 [Pa] ------- 79.22 [1/s]	1.034 [Pa] ------- 80.55 [1/s]	0.995 [Pa] ------- 80.21 [1/s]	1.069 [Pa] ------- 81.05 [1/s]	0.687 [Pa] ------- 81.35 [1/s]	0.992 [Pa] ------- 86.37 [1/s]
After microwave treatment	1.606 [Pa] ------- 82.34 [1/s]	1.804 [Pa] ------- 79.83 [1/s]	1.410 [Pa] ------- 79.98 [1/s]	1.713 [Pa] ------- 78.15 [1/s]	1.101 [Pa] ------- 84.24 [1/s]	1.368 [Pa] ------- 80.82 [1/s]

CONCLUSIONS

1. Concentrated microwave field influences on rheological properties of liquid whole egg.
2. Viscosity of liquid whole egg increases after microwave treatment.
3. Newtonian behaviour of LWE after microwave treatment appears at higher shear stress values in comparison to control LWE
4. Addition of higher level of vitamins into feed for laying hens resulted in decreasing of LWE viscosity.

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WPŁYW SKONCENTROWANEGO POLA MIKROFALOWEGO NA WŁAŚCIWOŚCI REOLOGICZNE MASY JAJOWEJ

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S t r e s z c z e n i e. Oddziaływanie mikrofalami może stać się alternatywną metodą w stosunku do tradycyjnej pasteryzacji. W pracy określono wpływ skoncentrowanego pola mikrofalowego na właściwości reologiczne masy jajowej. Stwierdzono, że lepkość masy jajowej wzrasta po oddziaływaniu mikrofalami. Dodatek większej ilości (niż standardowo) witamin oraz "Humokarbowitu" do paszy niosek powoduje zmianę parametrów reologicznych masy jajowej takich jak: lepkość, szybkość ścinania, naprężenie ścinające oraz odkształcenie.

S ł o w a k l u c z o w e: masa jajowa, skoncentrowane pole mikrofalowe, właściwości reologiczne, lepkość.