THE MODEL OF MEASURING WATER ACTIVITY IN FOOD PRODUCTS

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SUMMARY: One of the most important parameters of food products is the index "water activity". However,most of methods used for meauring Aw are characterised with substantial shortcoming. It is a large duration of measuring. That is why modelling the process of measuring Aw enabling to evaluate the influence of different factors on dynamical characteristics of devices is the essential stage of improving methods and technical facilities of measuring Aw.

INTRODUCTION: Consumer and technological properties of meat products are predetermined to a large extent by moisture content. But not so much total moisture content as that in form and binding power is of interest. At present the index "water activity" (Aw) has been finding increasingly growing use for evaluating binding power in food products. Microorganisms vital activity and kinetics of bio- and physical - chemical processes responsible for undesirable changes of food products quality depend on the Aw value (Troller and Christian, 1978; Scott, 1957; Labuza, 1977). At the same time water activity determines the nature of a number of heat-mass-exchange processes (drying, diffusion, osmosis, sorption etc.) due to its thermodynamical nature. To measure Aw hygrometrical methods consisting in determining the relative humidity of gaseous medium in the closed volume being in hygrothermal balance with the studied product are practised on a largest scale. Hygrometers of various types adapted for these purposes by means of applying special measuring chambers are widely used (Rodel, 1979; Von Elbe, 1986) . The greatest disadvantage limiting the use of this index both in research and directly in production is a large duration of measuring Aw by this and most of other methods (as a rule, 2 - 3 hours). At the same time the authors of this work do not know the attempts of developing mathematical models of water activity measuring processes uncluding devices of hygrometrical type, the use of which, to our opinion, will make it possible to make the analysis of factors influencing the duration of measuring and to outline the ways of its reduction.

MATERIALS and METHODS: Cooked doctor sausage (moisture 65 %) and fresh smoked special sausage (moisture 25 %) were taken as samples. Investigation was carried out with the help of VOLNA - 5 hygrometer (Angarsk EDBA) with digital indication, two types of standard humidity indicator (with mechanical filter and without it) being used. Indicators were placed in measuring chambers with volumes of 8 ml and 28 ml. Transfer characteristic was determined by recording hygrometer s readings on a diagram band. Uneven agitation was provided by connecting the measuring chamber with humidity indicator to the container with the studied sample. During this process the chamber with the indicator was held in the medium with relative humidity of 30 %.

RESULTS and DISCUSSION: Measuring Aw by devices of hygrometrical type is based on non-staionary heat-mass-exchange. During this process, first of all, moisture exchange of a food product surface with air in the closed volume takes place. Secondly,there occurs aqueous vapour diffusion in air medium of the measuring chamber. Thirdly, adsorption of moisture from air by moisture sensitive eiement goes on. Fourthly, internal heat-mass-exchange between a surface and inner layers of a sample also takes place. To study the process of measuring Aw by hygrometrical method we have developed a dynamical mathematical model which is based on the following assumptions:

- the inertial moisture transfer is negligibly small in comparison with moisture return from the surface of a sample;
- the time of balance establishment between the boundary layer and the surface of a sample is not taken into account;

- temperature (Θ), pressure, rate of moisture diffusion in air as well as mass-exchange characteristics and water activity of a sample in the process of measuring are constant.

The intensity of moisture exchange with air in the volume V of the chamber with assumptions mentioned above practically doesn`t depend only on the gradient of relative humidity on the surface of a boundary layer.

$$\Delta RH = f(RHb - RHc) , \qquad (1)$$

Where RHb and RHc are relative humidity of a boundary layer and in the chamber. While measuring Aw at the initial moment of time, in the chamber there appears the gradient of moisture which gradually lowers, relative humidity in the boundary layer is proportional to this gradient:

$$RHb = K1\ (Aw - RHc - RHi) = K1 \cdot \Delta RH \qquad (2)$$

Where RHi is the initial relative humidity in the chamber. Thus, transfer function W1(S) is approximated by the proportional link

$$W1(S) = K1 \qquad (3)$$

As it was determined before the rate of the boundary layer moisture exchange with the air of the chamber is considerably lower than the rate of its moisture exchange with the sample and is proportional to the coefficient of aqueous vapour diffusion in the air

$$dRH/dt = K2RHc \qquad (4)$$

Hence, transfer function W2(S) describes the proportional link

$$W2(S) = K2 , \qquad K1 \cdot K2 = F \cdot K \qquad (5)$$

Relative humidity in the chamber is prorortional to the amount of moisture accumulated in its volume V during the process t

$$RHc = K3 \int_0^t RHc(t)dt, \quad K3 = (R \cdot \Theta)/V \qquad (6)$$

Where R is the universial gas constant. Consequently, transfer function W3(S) describes the integrating link

$$W3(S) = K3/S \qquad (7)$$

In the case of humidity indicator being mounted at some distance from the sample surface, presence of mechanical and other filters, transfer function W4(S) must approximate the link of lag

$$W4(S) = \exp(-st1) \qquad (8)$$

Where t1 - is the time of pure transport lag, sec. Transfer function W4(S) reflects dynamical properties of moisture sensitive element of indicator and describes aperiodical link of the first order

$$W5(S) = K5/(T5S + 1) \qquad (9)$$

The structural scheme of the process corresponding to the developed model is presented on Fig. 1. Transfer function of the whole process along the canal "Aw - RHe" has the form

$$We(S) = \frac{W1(S) \cdot W2(S) \cdot W3(S)}{1 + W1(S) \cdot W2(S) \cdot W3(S)} \cdot W4(S) \cdot W5(S) \qquad (10)$$

After transformations the eguation of the whole process has the form

$$[T\ T5S^2 + (T + T5)S + 1]\ RHe(t) = K5(Aw - RHi)\ \exp(-st1) \qquad (11)$$

Where $T = V/(R\ O\ F\ K) = 1/(K1\ K2\ K3)$

As the incoming (Aw) and outcoming (RHe) parameters are measured in the same units, amplification constant K5 = 1. Having designated $T1^2 = T5T$; $T2 = T5 + T$, we write the equation in new designations

$$(T1^2S^2 + T2S + 1)\ RHe(t) = (Aw - RHi)\ \exp(-st1) \qquad (12)$$

Fig.2 shows a typical transfer characteristic of the process of measuring Aw in the conditions of hygrometrical type. As a result of processing experemental data, this process may be approximated in the common case by the differential equation of the second order. Constants T1 and T2 were determined graphically by traditional methods.

Test of model for adequacy by means of a computer showed a good coincidence with experimental data (the divergence is not more than 5 %) while substituting parameters obtained.

CONCLUSIONS: Analysis of the model and experimental results obtained makes it possible to conclude that the lag affects only when using measuring chambers of a large volume and moisture indicators with low dynamical characteristics (e.g.filters). The time constant reduces while reducing the chamber volume and enlarging the effective evaporation area of a sample. During this process the time constant of the chamber with a sample (T2) is not substantially changed when investigating various food products in the same conditions.

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Conditions of carrying out the experiment and the model s parameters

Food product	Chamber volume V, ml	Filter availabi-lity	Water activity Aw	Model s parameters (sec.) t1	T1	T2	T3	T4
Cooked	8,0	yes	0,965	0	18,5	71,0	70,7	0,3
sausage	8,0	no	0,965	0	0	54,0	54,0	0
	28,0	yes	0,965	5,0	30,8	110,0	109,7	0,3
	28,0	no	0,965	0	19,0	57,0	56,7	0,3
Fresh	8,0	yes	0,852	0	21,6	93,0	92,7	0,3
smoked	8,0	no	0,852	0	0	75,0	75,0	0
sausage	28,0	yes	0,852	9,2	41,1	153,0	152,7	0,3
	28,0	no	0,852	0	34,7	124,0	123,7	0,3

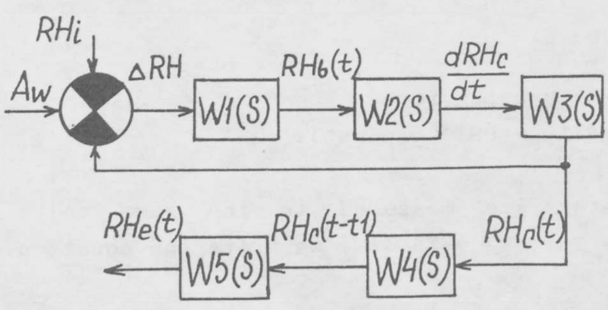

Fig.1. Structural scheme of the process of measuring Aw by devices of hygrometrical type

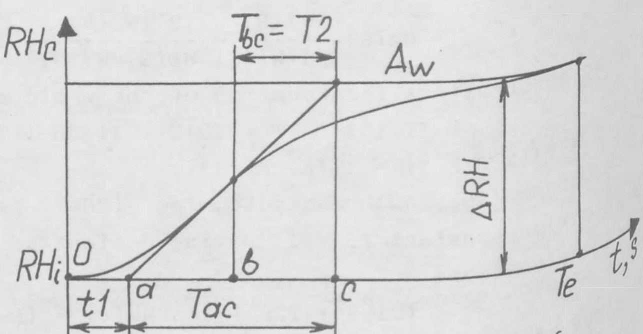

Fig.2. Typical surge characteristic of the process of measuring Aw by devices of hygrometrical type