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THE THEORY OF PSYCHROMETER AND WATER ACTIVITY IN FOODSTUFF

All biological phytogenous or animal-generated substances contain water varying from first percents till 90% and more. It provides for consistence and structure of foodstuff, and determines its storage stability. The moisture contained in the foodstuff is bonded with a foodstuff dry matter, with such moisture bond forms and energy varying. Being a component of the foodstuff, the moisture affects such important indexes, as organoleptic and rheological properties, microbial contamination, pathogenic microorganism growth, and quality deterioration as a result of physical, chemical and biological reactions.

For the foodstuff, however, not only the total amount of the moisture, but also its state is of great importance.

A water state in the foodstuff is determined by various characteristics, among which there are water-binding capacity, moisture bond energy and etc. Recently, of all the characteristics for determining the water state in the foodstuff a water activity index is the most perspective and informative.

A water activity notion (a_w) was introduced at the end of the fifties of the XX Century by W.I. Scott and H. Salwine. The water activity is used to quantitatively estimate how the water bond in the foodstuff qualitatively changes as against distilled water.

It is commonly supposed that distilled water and absolutely dry matter activity is equal to 1 and 0, respectively.

The water activity is a relative index describing the water state in the foodstuff. It is expressed through a ratio between the partial pressure of water vapors over the foodstuff, $P_{пр}$, at equilibrium, to the

Table 1

Foodstuff Storage Stability	Index		Storage Temperature, T°C
	a_w	pH	
A (perishable)	>0,95	>5,2	5
B (degradable)	0,91-0,96	5,0-5,2	10
C (long-time storable)	<0,95	<5,2	No cooling
	<0,91	<5,0	required

saturated pressure thereof, $P_н$, at the same temperature:

$$a_w = \frac{P_{np}}{P_н}, \quad (1)$$

In the opinion of a number of foreign researchers (L.Leister.,W.Rodel H. et alias) measuring a_w is one of the required foodstuff quality control types, without which no food processor can do nowadays. The experts of the Federal Research Center for meat industry (Kulbach, Germany) believe that measuring the value of a_W and pH is expedient to control the quality of non-canned meat products and sausages produced.

Since 1976 in EEC countries a_w and pH indexes have been introduced as mandatory for evaluating the quality of the meat products traded between these countries, and in the USA these indexes were introduced into one of Food and Drug Administration Instructions (Federal Register, Volume 44 No. 53, March 16, 1979 г.)

EC countries has adopted a concept for classifying the meat products into three groups by storage life depending on pH and a_w. These groups are represented in Table 1. [1]

Based on a water activity value one may control the chemical stability and fermentation capacity of the foodstuff, determine their contamination rate and prepare a stability map.

However, with respect to a_w M.Z. Tracy, an Australian scientist, has the following opinion: [2]

Using the water activity notion, as an important forecast parameter, allowed us to solve such a great number of real problems in various branches of knowledge, that it has taken an unshakable place among the specific optimal methods of processing the data relating to foodstuff properties and behavior: unshakable, but, as we have seen for ourselves, becoming flaked away and cracked under the load of physiochemical research data, i.e. for the time being no theoretical basics of thermodynamic water activity index have been developed and its physical sense has not been established.

In many devices the water activity index is determined as relative air humidity, when equilibrium is reached over the foodstuff. The relative humidity is an important thermodynamic parameter describing an air state. This index is determined by a psychrometric formula that establishes an interrelation between the pressure of vapor in air and wet bulb thermometer temperature [3]. This interrelation is represented as follows

$$P_n = P_m - 6{,}78\,(t_c - t_m)\,\frac{B}{10270}, \text{ kg\m}^2 \text{ or Pa} \quad (2)$$

Where:

P_n – partial pressure of the vapor contained in air, Pa;

P_m – saturated vapor pressure at the wet bulb thermometer temperature, Pa;

t_c – wet bulb thermometer temperature, K;

B – barometric pressure, Pa.

Schprung expressed B in mm of mercury. From the expression this value is in kg\m². Factor 6,78 is derived by multiplying its Schprung value of 0,5 by the specific mercury weight of 13,56.

$$t_c = 18$$

$$t_m = -13$$

This formula was empirically derived more than 150 years ago by Schprung, a German scientist. Based on a psychrometer reading the partial pressure of the water vapors in air may be calculated using this formula.

But A.A. Gouhman, Professor from Russia, notes that one and half century has passed since the first studies devoted to a psychrometer problem. Nevertheless, for the time being neither in terms of theory nor practice the problem can be deemed solved. He does specify that a characteristic prevailing in metrology contains an empirically determinable quantity, a psychrometric factor. Within the framework of generally accepted theory based on a saturation notion, we not only fail to obtain the correct value of this quantity, but also to explain its qualitative aspects and changes dependable on various factors.

As we have seen for ourselves, for the time being the physical sense of the psychrometric formula has not been clarified and the value of the psychrometric factor has not been accurately determined. In this connection let's consider the theoretical basics of psychrometer. In the theory of psychrometer to evaluate a heat-mass-exchange process more precisely it is required to consider it thermodynamically, i.e. to thermodynamically evaluate each water molecule state. This approach allows us to take into account the laws of quantum mechanics. According to Russian scientist Pr. A.S. Ginzburg surface phenomena taking place, when a liquid interacts with a solid, are essentially associated not only with physical, but also with chemical interactions. Considering these complicated phenomena on a joint basis presents considerable difficulties, especially in terms of obtaining quantitative parameters; in this context using the methods of contemporary quantum mechanics is very perspective. Based on the laws of thermodynamics we have obtained a relative air humidity versus ambient and wet bulb thermometer temperature response characteristic that takes into account changes in in-air vapor enthalpy and dry air pressure. This formula shows that the psychrometric factor is variable and depends on the dry air pressure and in-air vapor enthalpy.

$$\varphi = a_w = \left[\frac{p_m - \dfrac{c_{cв}(\theta_{np} - t_m) \times P_{CBtm}}{0{,}622 \times I_m}}{P_H} \right] \times \frac{P_{CB\theta_{np}} \times I_m}{P_{CBt_m} \times I_{m\theta_{Gm}}}, \quad (3)$$

Where

P_m – saturated vapor pressure at t_m;

$C_{cв}$ – average specific heat capacity of vapor;

θ_{np} – foodstuff temperature;

t_m – water temperature;

I_m – enthalpy of vapor on the bottom of δ layer at t_m;

$P_н$ – saturated vapor pressure at t_{np};

$P_{cв_{\theta m}}$ – dry air pressure at θ_m;

$P_{cв_{tm}}$ – pressure of dry air over the foodstuff on the top of δ layer at t_m;

$I_{m\theta_{np}}$ – enthalpy of vapor over the foodstuff on the top of δ layer at θ_{np};

According to the formula the water activity is a ratio between the enthalpy of water in an upper foodstuff layer and that of distilled water, less the enthalpy of residual foodstuff moisture, when equilibrium with the dry air is reached at the specified temperature.

When equilibrium is reached between the foodstuff and air during a sorption process, the foodstuff temperature is equal to ambient temperature, i.e. to air temperature. In this case, the *water activity is equated to relative air humidity.*

Based on the forgoing we have derived a universal psychrometric formula that enables us to determine the essence of the psychrometric factor and establish the physical sense of the water activity index. Using *this formula we can determine the* relative air humidity, when the temperature of wet and dry bulb thermometer is measured, and the water activity, when the temperature of the foodstuff and wet bulb thermometer is measured, while the moisture is freely vaporizes therefrom.

Developing the theoretical basics of psychrometer and defining the physical sense of thermodynamic water activity index for the foodstuff have given a possibility to develop new methods of their determination and create more accurate unique devices. Existing devices require several hours to determine the water activity, while the methods and devices newly developed may determine this index within 4-5 minutes.

The methods and devices newly developed for measuring the water activity and relative air humidity enable us to set *optimal modes for processing the* foodstuff, when they are minced, mixed, heat treated, dried up and stored.

1. *Myounh G.D.* Microbiology M. 1985
2. *Dokuort R.D.* Water in Foodstuff M. 1980.
3. *Spenser-Gregori K. Rourke E.* Gigrometer M., 1963.