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WATER ACTIVITY CONCEPT FOR SAFETY FOOD STORAGE

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ABSTRACT

It is well known that there are at least three factors of fundamental importance in determining the safety and longevity of stored food: water, temperature and oxygen. The outlines of this paper are water, especially the energy status of the water, measured end expressed in terms of the water activity. Water activity is still not commonly used, but has several distinct advantages for specifying conditions related to the safety of the foods and their storage. Basic principals and application of water activity in safety food storage are examined. On the base of concrete results for water activity of Bulgarian market foods and row materials for their production, advantages of water activity management over measurement and controlling only the water content is demonstrated. The selected examples demonstrate that water activity measurement is quicker, easier and more informative than water content measurement.

1. INTRODUCTION

Two moisture measurements are required to completely characterize the state of water in a material such as a food product sample. The first measurement is water content. Water content is a measure of the amount of water in the sample and can be directly determined by drying a sample.

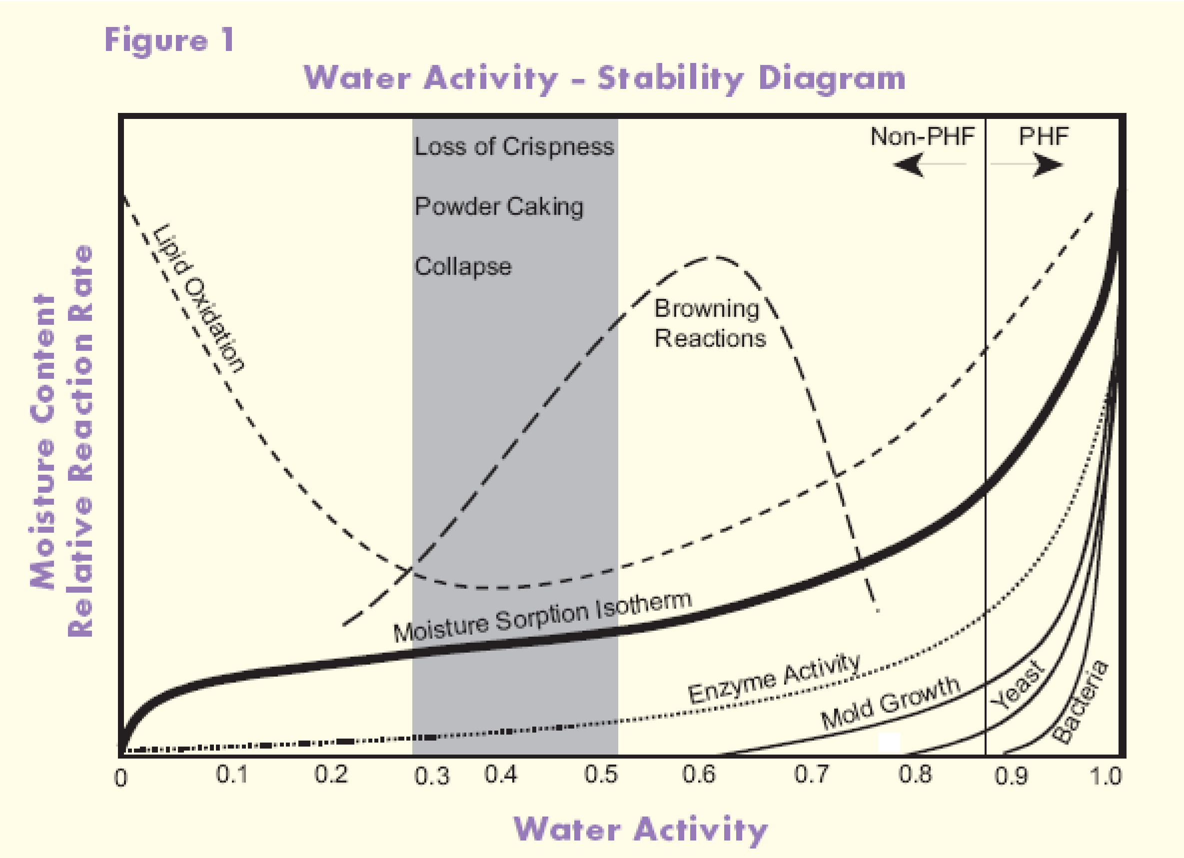
The second measurement required to characterize the state of water is the water activity. Water activity (a_W) is the ratio of the vapour pressure of water in a material (p) to the vapour pressure of pure water (p_o) at the same temperature. Relative humidity of air is the ratio of the vapour pressure of air to its saturation vapour pressure. When vapour and temperature equilibrium are obtained, the water activity of the sample is equal to the relative humidity of air surrounding the sample in a sealed measurement chamber. Multiplication of water activity by 100 gives the equilibrium relative humidity (ERH) in percent.

$$a_w = p/p_o = \text{ERH (\%)} / 100$$

As described by the above equation, water activity is a ratio of vapour pressures and thus has no units. It ranges from 0.0 a_w (bone dry) to 1.0 a_w (pure water). A water activity measurement of 0.80 means that the vapour pressure of the sample is eighty percent of the vapour pressure of pure water at the same conditions.

Water activity predicts safety and stability with respect to microbial growth, chemical and biochemical reaction rates, and physical properties. Figure 1 shows stability in terms of microbial growth limits and rates of degradative reactions as a function of water activity. Therefore, by measuring and controlling the water activity, it is possible to:

- predict which microorganisms will be potential sources of spoilage and infection;
- maintain the chemical stability of products;
- minimize nonenzymatic browning reactions and spontaneous autocatalytic lipid oxidization reactions;
- prolong the activity of enzymes and vitamins;
- optimize the physical properties of products such as moisture migration, texture, and shelf life.



2. EXPERIMENTAL DATA

The water activity (a_W) was measured with a water activity meter AquaLab 3TE (Decagon, USA) - internal temperature control model, with thermoelectric (Peltier) components to maintain internal temperature. Though a_W of most products varies by less than ± 0,002 per °C, the measurements was made at 25°C. AquaLab uses the chilled-mirror dew-point technique for measuring a_W of the sample. Because this is a primary measurement method, no calibration was necessary. The apparatus was only check (verified) for linear offset periodically by using a salt solution (a_W levels 0,984; 0,760; 0,500 and 0,250) and distilled water (a_W 1,000).

Samples ware left intact if possible to ensure that the a_w is not altered. If necessary, the sample material was cut to fit the sampling cup. A sample that cannot be analysed immediately upon receipt was stored. For long term storage, glass jars or mylar bags was used. Once prepared, the sample was analyzed the same day. Refrigerated and frozen samples were prewarmed to ambient temperature to reduce the equilibration time and to give a more accurate reading. Multi-component samples or samples that have outside coatings was measured by crushing, slicing or grinding before putting it in the sample cup. In this case a_W was read as average water activity of the entire sample.

3. RESULTS AND DISCUSSION

3.1 Microbial Growth and Limiting Microorganism Growth

Water activity indicates the amount of water in the total water content which is available to micro-organisms. Each species of micro-organism (bacteria yeast and mould) has its own minimum a_w value below which growth is no longer possible. This limit corresponds to the 'suction power' of the various organisms, i.e. to the osmotic pressure they create and which must be higher than in the aqueous phase of food, to absorb from the food the water needed for metabolic activity and growth (see table below). By measuring the a_w value of foodstuffs it is possible to determine which micro-organisms will not be able to develop on them.

Typical growth limits function of a_w are 0.91 - 0.95 for most bacteria; 0.88 - most yeast; 0.80 - most mildew; 0.75 - halophile bacteria; 0.70 - osmiophil yeast; 0.65 - xerophile mildew. The water activity level that limits the growth of the vast majority of pathogenic bacteria is 0.90 a_w, 0.70 a_w for spoilage moulds, and the lower limit for all micro-organisms is 0.60 a_w.

Table 1 Foods with a_W range 1,00 – 0,95

Microorganisms inhibited by lowest a_W in range 1,00 – 0,95	*Pseudomonas, Escherichia, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens,* some yeasts		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Mineral water		1,000 / 25ºC	
Spread cheese	Cheese, curds, vegetable oil, emulsifier salts (E450, E452, E339, E1412), flavours	0,992 / 25ºC	
Potato Balls	Potatoes, mashed potatoes, cottage cheese, breadcrumbs, onions, salt, sour cream, dill, parsley, black pepper, E 202, E 211	0,991 / 25ºC	The classic vegetarian balls
Mayonnaise	Sunflower oil, vinegar, sugar, salt, E1414, E 330, E412, E415, , E202, E211,	0,989 / 25ºC	
Bean dish (Gozba)	Beans, roasted and fried peppers, tomato puree, carrots, vegetable oil, tomatoes, sugar, aubergines, onions, salt, herbs, modified starch, E 202, E 211	0,989 / 25ºC	Beans cooked from an authentic recipe
Hot Peppers in Tomato Sauce	Tomatoes, hot peppers, vegetable oil, salt, sugar, vinegar, modified starch, E 202, E 211	0,986 / 25ºC	A serious Bulgarian lunch can't do without hot peppers
Plant production bread Dobrudja type	Wheat flour, yeast, salt	0,971 / 25ºC	
Mustard	Mustard, refined sunflowers oil, vinegar, salt, sugar, spices, horse-radish, stabilizer (E412, E415, E224), and preservatives (E211, E330), water	0,970 / 25ºC	
Bread Stara Zagora type cut in slices	Wheat flour, yeast, salt	0,964 / 25ºC	
Tomato Chutney	Sweet peppers, tomato puree, carrots, vegetable oil, tomatoes, aubergines, sugar, salt, modified starch, E 202, E 211	0,955 / 20ºC	The tomato chutney is one of the first industrially prepared canned foods in Bulgaria. Since the beginning, there is a great variety of brands of different companies.
"Snow-White" Salad	Strained yogurt, fresh cucumbers, mayonnaise, sour cream, dill, salt, garlic, E 202, E 211	0,950 / 20ºC	"Snow-white" salad comes from Greece along with the Ouzo

Table 2 Foods with a_W range 0,95 – 0,91

Microorganisms inhibited by lowest a_W in range 0,95 – 0,91	*Salmonella, V. parahaemolyticus, C. botulinum, Serratia, Lactobacillus, Pediococcus,* some yeasts, yeasts (*Rhodotorula, Pichia)*		
Example of foods within this range			
Food	Ingredients	Water activity /	Remarks

		temp. ºC	
Ham from poultry fillet	Poultry fillet, salt, E250, E300, E330, E407, E452	0,942 / 25ºC	
Caramel filling	oil, sugar, stabilizer, salt, vanillin, preservative	0,930 / 25ºC	Filling for Croissant
Cheesy banitza	Wheat flour, cheese	0,929 / 25ºC	savoury cheese pastry
White chocolate cream		0,920 / 20ºC	

Table 3 Foods with a_W range 0,91 – 0,87

Microorganisms inhibited by lowest a_W in range 0,91 – 0,87	Many yeasts (*Candia, Torulopsis, Hansenula), Micrococcus*		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Dietetic Ham Sausage	Poultry meat, salt, E407, E250, E452, E621, E1442, E300	0,905 / 25ºC	
Fermented sausage (salami)	veal meat, pork meat, bacon, salt, spices, E120, E250, E330	0,863 / 25ºC	

Table 4 Foods with a_W range 0,87 – 0,80

Microorganisms inhibited by lowest a_W in range 0,87 – 0,80	Most moulds (mycotoxigenic penicillia), *Staphilococcus aureus,* most *Saccharomyces, Debarymyces*		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Raw-dried meat salami	veal, pork, salt and spices	0,847 / 25ºC	
Jam "Strawberry"	strawberries, sugar, pectin E440, lemon acid E330	0,821 / 25ºC	
Croissant with strawberry filling	Flour, strawberry jams filling, margarine, sugar, butter, egg powder, glucose, salt, and yeast. E471, E282	0,815 / 25ºC	
Margarine	Vegetable oil, water, E322, E471, E330, E202, E160, E320, E321	0,810 / 25ºC	
Jam "Raspberry"	raspberries, sugar, pectin E440, lemon acid E330	0,801 / 25ºC	

Table 5 Foods with a_W range 0,80 – 0,75

Microorganisms inhibited by lowest a_W in range 0,80 – 0,75	Most halophilic bacteria, mycotoxigenic aspergilli		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Apricot jam	apricot, sugar, pectin E440, lemon acid E330	0,797 / 25ºC	
Tomato Chutney Parvomai	Sweet peppers puree, tomato puree, vegetable oil, sugar, salt, space	0,790 / 20ºC	
Butter		0,780 / 25ºC	

Table 6 Foods with a_W range 0,75 – 0,65

Microorganisms inhibited by lowest a_W in range 0,75 – 0,65	Most xerofilic moulds (*Aspergilus chevalieri, A. candidus, Wallemia sebi) Sacharomyces bisporus*		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Corn cereals		0,710 / 25ºC	
Wheat cereals		0,675 / 25ºC	
Wheat flour type 500		0,650 / 25ºC	

Table 7 Foods with a_W in range 0,65 – 0,61

Microorganisms inhibited by lowest a_W in range 0,80 – 0,75	Most osmophilic yeasts (*Zygosacharomyces rouxii),* few moulds (*Aspergillus echinulatus, Monascus bisporus)*		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Pasturma	Cured dried beef, mild flavour, spices, salt, vacuum packed.	0,640 / 25ºC	
Wheat flour type 700		0,620 / 25ºC	

Table 8 Foods with a_W below 0,61

Microorganisms inhibited by lowest a_W below 0,61	No microbial proliferation		
Example of foods within this range			
Food	Ingredients	Water activity / temp. ºC	Remarks
Wheat flour type 1150		0,570 / 25ºC	
Dried plum		0,541 / 25ºC	
Dried apple		0,503 / 25ºC	
Finetti Cream brown		0,339 / 25ºC	
Finetti Cream white		0,322 / 25ºC	

3.2 **Chemical Reactivity**

Water activity influences not only microbial spoilage but also chemical and enzymatic reactivity. Water may influence chemical reactivity in different ways; it may act as a solvent, reactant, or change the mobility of the reactants by affecting the viscosity of the system. Water activity influences nonenzymatic browning, lipid oxidization, degradation of vitamins and other nutrients, enzymatic reactions, protein denaturation, starch gelatinization, and starch retrogradation (see Figure 1). Typically, as the water activity level is lowered, the rate of chemical degradative reactions decreases.

3.3 **Physical Properties**

Besides predicting the rates of various chemical and enzymatic reactions, water activity affects the textural properties of foods. Foods with high a_w (Table 1 and 2) have a texture that is described as moist, juicy, tender, and chewy. When the water activity of these products is lowered, undesirable textural attributes, such as hardness, dryness, staleness, and toughness, are observed. Low a_w products normally have texture attributes described as crisp and crunchy, while these products at higher a_w levels change to soggy texture. Critical water activities determine where products become unacceptable from a sensory standpoint.

3.4 **Caking, Clumping, Collapse and Stickiness**

Water activity is an important factor affecting the stability of powders and dehydrated products during storage. Controlling water activity in a powder product maintains proper product structure, texture, and stability, density, and dehydration properties. Knowledge of the water activity of powders as a function of moisture content and temperature is essential during processing, handling, packaging and storage to prevent the deleterious phenomenon of caking, clumping, collapse and stickiness. Caking is water activity, time, and temperature dependent and is related to the collapse phenomena of the powder under gravitational force.

3.5 **Moisture Migration**

Because water activity is a measure of the energy status of the water, differences in water activity between components is the driving force for moisture migration as the system comes to an equilibrium. Thus, water activity is an important parameter in controlling water migration of multicomponent products. Some foods contain components at different water activity levels, such as filled snacks or cereals with dried fruits. By definition, water activity dictates that moisture will migrate from a region of high a_w to a region of lower a_w, but the rate of migration depends on many factors. Undesirable textural changes can result from moisture migration in multicomponent foods. For example, moisture migrating from the higher aw dried fruit into the lower a_w cereal causes the fruit to become hard and dry while the cereal becomes soggy.

4. CONCLUSION

On the base of concrete results for water activity of Bulgarian market foods and row materials for their production, advantages of water activity management over measurement and controlling only the water content is demonstrated. The selected examples demonstrate that water activity measurement is quicker, easier and more informative than water content measurement.

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